Spawning occurs in nearshore coastal waters, typically from mid August to mid October with a peak in September (e.g., Ditty et al. 1988, Comyns 1997, Wilson and Nieland 1994). In the northwestern Gulf, spawning occurs in nearshore waters and evidence suggests that mature adults congregate near the mouths of passes and inlets (Pearson 1929, Peters and McMichael 1987, Comyns et al. 1991). While females can mature as early as age 2 (fraction mature = 0.05), the fraction mature does not achieve 90-100% until ages 5 and 6. Based upon Porch (2000), a 6-year-old female would produce on the order of 8.3 million eggs annually, whereas a 10-year-old female red drum produces on the order of 16 million eggs annually. The life span of red drum extends to at least age 30. Thus, red drum has a long life span and is characterized by high fecundity.

Eggs and yolk-sac larvae are planktonic and are transported onshore where post larvae settle in seagrass beds, wetlands and estuaries (Reagan 1985). The young rear in these nursery grounds reaching their juvenile stage. Adults tend to travel in schools close to the shore, however, some larger fish remain in the open Gulf year round (Reagan 1985).

Table 25 lists the SEAMAP larval densities of red drum (± 95% CI) and seawater usage projections by zone. The distribution of red drum larvae is restricted to the nearshore depth zones 1-3 (0-200 m) for the Central and Western Planning Areas and depth zones 1-2 (0-60 m) for the Eastern Planning Area. This pattern is consistent with the observations of Gallaway et al. (2007) who found that, based upon an analysis of SEAMAP data, the density of larval red drum in the GOM decreased exponentially with distance from shore. This pattern is exemplified in the Central Planning Area. There is better than a 93% decrease in red drum density from zones C1 to C2 and another 70% decrease from zones C2 to C3. Based on these species distribution data, no new CWIS are anticipated for red drum spawning areas and entrainment impacts from offshore CWIS are not an issue for this species

## Life-History Background

Red drum have been the focus of intense scientific study for many years. Considerable life-history information has been compiled for this species including the necessary egg and larval mortality and duration estimate needed for an entrainment loss assessment. These data are presented below. Assessment life-history summaries are presented in Appendix Table D7.

The derivation of life-history values for eggs, larvae and three juvenile stages of red snapper are detailed in Gallaway (2005). Much of the following is taken from Gallaway (2005).

Table 25. SEAMAP larval densities for red drum (± 95% CI) and seawater usage projections by zone. Shaded area denoted the only zones where future CWIS activity is projected. No entrainment is projected.

| Zone | Larval Density (no./m3) | | | Water Usage (Million m3/day) | Daily Entrainment (Millions) | | |
|---|---|---|---|---|---|---|---|
| | Mean | LCL | UCL | | Mean | LCL | UCL |
| E1 | 0.4370516 | 0.1941797 | 0.6799235 | 0 | 0 | 0 | 0 |
| E2 | 0.0079176 | 0.0022171 | 0.0136181 | 0 | 0 | 0 | 0 |
| E3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C1 | 0.7700569 | 0.4935585 | 1.0465553 | 0 | 0 | 0 | 0 |
| C2 | 0.0513088 | 0.0277172 | 0.0749004 | 0 | 0 | 0 | 0 |
| C3 | 0.015419 | 0 | 0.03182 | 0 | 0 | 0 | 0 |
| C4 | 0 | 0 | 0 | 0.05678 | 0 | 0 | 0 |
| C5 | 0 | 0 | 0 | 0.91986 | 0 | 0 | 0 |
| W1 | 0.8754962 | 0.3860068 | 1.3649855 | 0 | 0 | 0 | 0 |
| W2 | 0.1270838 | 0.0903891 | 0.1637785 | 0 | 0 | 0 | 0 |
| W3 | 0.0023236 | 0.0005137 | 0.0041335 | 0 | 0 | 0 | 0 |
| W4 | 0 | 0 | 0 | 0.01514 | 0 | 0 | 0 |
| W5 | 0 | 0 | 0 | 0.17791 | 0 | 0 | 0 |

Gallaway (2005) noted that the identification of larval and juvenile stages of red drum are actually based on a combination of size, habitat-use, and seasonal abundance patterns as opposed to being true biological stages. The planktonic larval stage covers the size range from hatch (1.5 to 2 mm SL to 8 mm SL). The planktonic stage is followed by an early benthic or juvenile 1 stage which he defined as the size range from 8 to 24 mm SL. These individuals mainly utilize seagrass beds or other vegetated areas as habitat. Up to 24 mm SL, the early benthic juveniles are fully vulnerable to the benthic sled plankton sampling gear (e.g., Rooker et al. 1999), but sizes ≥25 mm SL are not fully vulnerable. It is about this size that juvenile red drum appear in shoreline bag seine studies (e.g., Scharf 2000). Gallaway (2005) thus assumed that the second juvenile stage began at about 25 mm SL. These larger juveniles were subdivided into two groups—juvenile 2 and juvenile 3. The first stage covers the period from October to March (juvenile 2) and the second (juvenile 3) is for juveniles from April to August. August is the end of the first year, assuming spawning occurred in September of the previous year. This division was used because a marked reduction in mortality is evident for the larger juvenile red drum that occur in April-June as compared to the smaller juveniles present in October-March (Scharf 2000).

### *Eggs*

The egg stage daily instantaneous mortality rate of 0.4984 used for red drum is based upon Atlantic croaker as originally proposed in e$^2$M (2005). The use of croaker mortality rate as a suitable proxy value for red drum was supported by Dr. Kenneth Rose of Louisiana State University (as cited pers. comm. in e$^2$M 2005). The duration estimate of 1-

day is based largely on laboratory studies as cited in $e^2M$ (2005). We have found no better estimates and accept these values as reasonable assumptions.

***Larval Stage***

$e^2M$ (2005) used 20 days as the base, high and low duration period (i.e., no variation) for the larval stage of red drum, citing Rooker et al. (1999) and Stunz et al. (2002). Rooker et al. (1999) noted that peak densities of benthic settlers were observed for individuals 8-9 mm (corresponding ages = 20-24 d), suggesting that recruitment to seagrass meadows follows a planktonic period of approximately 20 days. Gallaway (2005) suggested that the median of 22 days be used for the base estimate, and that 20 and 24 days be used as the low and high estimates, respectively. This would be consistent with Rooker et al.'s (1999) observation that full recruitment to the first benthic juvenile stage occurred at ages from 20 to 24 days.

$e^2M$ (2005) used 0.25, 0.33 and 0.17 as the base, high, and low estimates of daily instantaneous mortality, respectively. These values are derived from Comyns (1997) as described in Table G-13 in $e^2M$ (2005). Gallaway (2005) disagreed with the use of 0.17 $d^{-1}$ as the low estimate and 0.33 $d^{-1}$as the high estimate. The 0.17 $d^{-1}$ value was from a single cruise where more than one cohort was represented in the collections and because of this artifact it is not a reliable estimate for the low end of the range. The value 0.33 $d^{-1}$ was Comyns' (1997) best estimate for larvae in the 2-5 mm range, not the high end of the size range. If 0.17 $d^{-1}$ is used as the low end, then the highest value observed on a cruise should be used for the high end estimate. However, neither of these estimates would be appropriate because they were based on incomplete sampling. In contrast, Comyns et al. (1991) reported a mean estimate of 0.51 $d^{-1}$ (SE = 0.207) for larval red drum collected in 1984 and 1985 in the Mississippi Bight area east of the mouth of the Mississippi River. This value should also be considered as a candidate for the high value.

Gallaway (2005) recommended that $M = 0.3009$ $d^{-1}$ be used for the base case based upon the following. Comyns (1997) value of $M = 0.33$ $d^{-1}$ was assumed to be the best estimate for larvae 2-5 mm. Gallaway (2005) used a value of $M = 0.1365$ $d^{-1}$ for early stage benthic juveniles (see below). The value $M = 0.233$ $d^{-1}$ represents a linear interpolation between 0.33 $d^{-1}$ and the 0.1365 $d^{-1}$ value for larvae between 6 and 8 mm. Using the average of the total mortality obtained by applying these rates to the respective size intervals yields an estimate of 0.3009 $d^{-1}$. The upper and lower bounds (0.2225 and 0.3793) were calculated using Comyns' (1997) 95% confidence interval for the 0.33 estimate.

Gallaway (2005) submitted his estimates of larval red drum instantaneous mortality rates and those proposed by $e^2M$ (2005) to Dr. Comyns for his evaluation. Dr. Comyns concluded (Gallaway 2005, Appendix 1) that the Gallaway (2005) estimates were more realistic than those proposed by $e^2M$ (2005). Dr. Comyns also noted that the value of $Z = 0.17$ was not a reliable mortality estimate and the high estimate of 0.33 was likely somewhat understated.

***Juvenile 1 Stage***

Gallaway (2005) concurred with the estimates of the daily instantaneous mortality rates (base, high, and low) being used for this life history stage by e$^2$M (2005) based on Rooker et al. (1999). Gallaway (2005) disagreed with the base and low stage duration estimates being used by e$^2$M (2005); i.e., 12 days for each. The high end estimate of 20 days seemed appropriate. Based upon Rooker et al. (1999), Gallaway (2005) concluded that the stage duration likely ranged between 17 and 20 days with the median estimate being about 18.5 days. His view was that the 12-day period referenced in Rooker et al. (1999) was not intended to be interpreted as the total stage duration, but was rather a common time frame used to make direct comparisons of mortality rates between 1994 and 1995. Gallaway (2005) submitted his argument to Dr. Rooker (Gallaway 2005, Appendix 2).

Dr. Rooker confirmed that the 12-d period over which red drum mortality rates were estimated was not intended to define a specific stage in the life history of an individual, but instead was an interval over which a reliable estimate of mortality could be determined (Gallaway 2005, Appendix 2). He noted that the upper end of the interval is on the order of 40 days and that even this is not intended to define the end of the postsettlement stage. If the planktonic stage extends to ages 20 to 22 days and 40 days is a minimum estimate of age near the upper end of this stage, then the duration of this stage should range between 18 and 20 days.

Gallaway (2005) used Rooker et al.'s (1999) age-length relationships to calculate age at the beginning and end of the size range included within this stage to estimate stage duration. One can evaluate these estimates by using observed growth rates (mm/day) to estimate the days required to achieve the growth between the size of fish at the beginning and end of the stage. In 1994, the observed increase in size was 16 mm (i.e., 8 mm SL to 24 mm SL, Rooker et al. 1999). Rooker et al. (1999) observed a growth rate of 0.58 mm/d in 1994. This yields a duration estimate of about 28 days. In 1995, the observed increase in size was 15 mm (9 mm to 24 mm SL) and the growth rate was 0.62 mm/d (Rooker et al. 1999). The estimated stage duration would thus be about 24 days. However, if one uses 20 mm SL as the maximum size, the total growth for each year would be 12 and 11 mm, respectively. These values yield stage durations of 20 and 18 days, respectively.

Independent evaluations of postsettlement red drum growth rates are provided by Rooker and Holt (1997) based on data obtained from the Aransas Estuary, Texas during September to December 1994. Growth for six successive cohorts ranged from 0.50 to 0.82 mm/d, averaging 0.63 mm/d (95% CI = 0.54 to 0.72 mm/d). Applying this estimate to the observed 16 mm (24 mm end point) increase yields an estimated stage duration of 25 days; this value applied to a 12 mm increase (maximum size of 20 mm) yields an estimate of 19 days. However, the data used by Rooker and Holt (1997) is a large part of the data set used by Rooker et al. (1999). Therefore, it is not truly an independent data set.

However, Stunz et al. (2002) reported an overall postsettlement growth rate of 0.45 mm/d for 10 to 33 mm SL red drum in Galveston Bay, Texas. To eliminate the potential effects of movement among habitats, they evaluated the growth of fish in enclosures around oyster-reef, non-vegetated bottoms, salt marsh, and seagrass habitats. The observed growth rates were 0.12, 0.21, 0.40, and 0.42 mm/day, respectively. Growth rates in enclosures approximated natural growth rates. These growth rates would suggest a longer stage duration than was estimated above.

Based upon these data, (Gallaway (2005) proposed that a conservative stage duration estimate for postsettlement red drum was 18.5 days with a range of 17 to 20 days.

***Juvenile 2 Stage***

e$^2$M (2005) used 0.0054 (0.00478 to 0.00609) as the instantaneous mortality rate for this life stage based upon Scharf (2000). They observed that those values are the mean and 95% CI's of reported daily mortalities for 20 years and nine Texas estuaries from Sabine Lake to the Laguna Madre as reported by Scharf (2000). The corresponding stage durations used by e$^2$M (2005) were 166 for the base and low duration cases, and 162 days for the maximum stage duration. These are calculated values for one half of the remainder of the first year. The other half is assigned to the Juvenile 3 stage discussed below.

Scharf's (2000) estimates of mortality were calculated from the observed declines in CPUE that occurred from the peak values observed in fall and winter (November/December) to the end of spring. The stage begins in October, but these juvenile fish were not fully recruited to fishing gear until November and December, and the peak usually occurred in December. Thus, overall the stage duration covered a 273-d period with the mortality estimates based upon a subset of the data from December (typically) through June. Since the smallest sizes were not covered by the analysis, mortality is likely somewhat underestimated. Further, arbitrarily reducing the stage duration period to only 166 days rather than using the 212 days over which the regressions were calculated, or the 273 days over which the $\geq$25 mm SE stage occurs, is not explained or justified in e$^2$M (2005).

Apparent mortality based upon CPUE declines does appear to be typically higher in the December-March periods as compared to April-June periods (Scharf 2000). Gallaway (2005) restricted the mortality estimates to data from Sabine Lake and Galveston Bay as these Texas estuaries are closest to the central part of the red drum range. He then used Figure 4 in Scharf (2000) to calculate survival based on the December and March CPUE values, and converted survival to a daily mortality rate for each estuary (i.e., total mortality ÷121 days in the sample period). Using this approach, Gallaway (2005) obtained a daily instantaneous mortality rate of 0.0079 for Galveston Bay and 0.0108 for Sabine Lake. These constituted high and low ends of the range and the median (0.0094) was used for the base case.

Based on Scharf (2000), Gallaway (2005) estimated this stage extends from October-March (180 days). Up to now, we have accounted for 41.5days (from egg to the juvenile 1 stage) which occur in the September/October period. Thus, for the base case, the duration of the juvenile 2 stage is estimated at 168.5 days (180 days-11.5 days in October). In the low case above, egg to the juvenile 1 stage occurs over a total of 38 days (September plus 8 days in October). The stage duration for the low duration estimate is 180 days-8 or 172 days. Similarly, the high case described above extends for 45 days. This would allocate 15 days in October; 180-15 yields a stage duration of 165 days.

### *Juvenile 3 Stage*

Like $e^2M$ (2005), Gallaway (2005) used the Porch (2000) red drum stock assessment to approximate the daily instantaneous mortality rate ($M = 0.0018\ d^{-1}$) for the balance of the age-0 year (155 days).

### *Adults*

Estimates for adult natural and fishing mortality (Appendix Table D8) are those derived by (EPRI 2005).

## Spotted Seatrout (*Cynoscion nebulosus*)
## Rank 2: (Recreational Fishery)

The spotted seatrout is found in nearshore waters of the GOM (Figure 21) inhabiting sandy bottoms, seagrass beds, and estuaries (McEachran and Fechhelm 2005). This species ranks 2nd in the GOM recreational fishery with 13.0 million pounds landed annually. The annual landing by weight is almost identical to that of red drum (13.1 million pounds); however, 10.7 million seatrout are taken annually compared to only 2.8 million red drum. The spotted seatrout is the premier game fish in Texas waters with more than 996,000 fish landed annually.

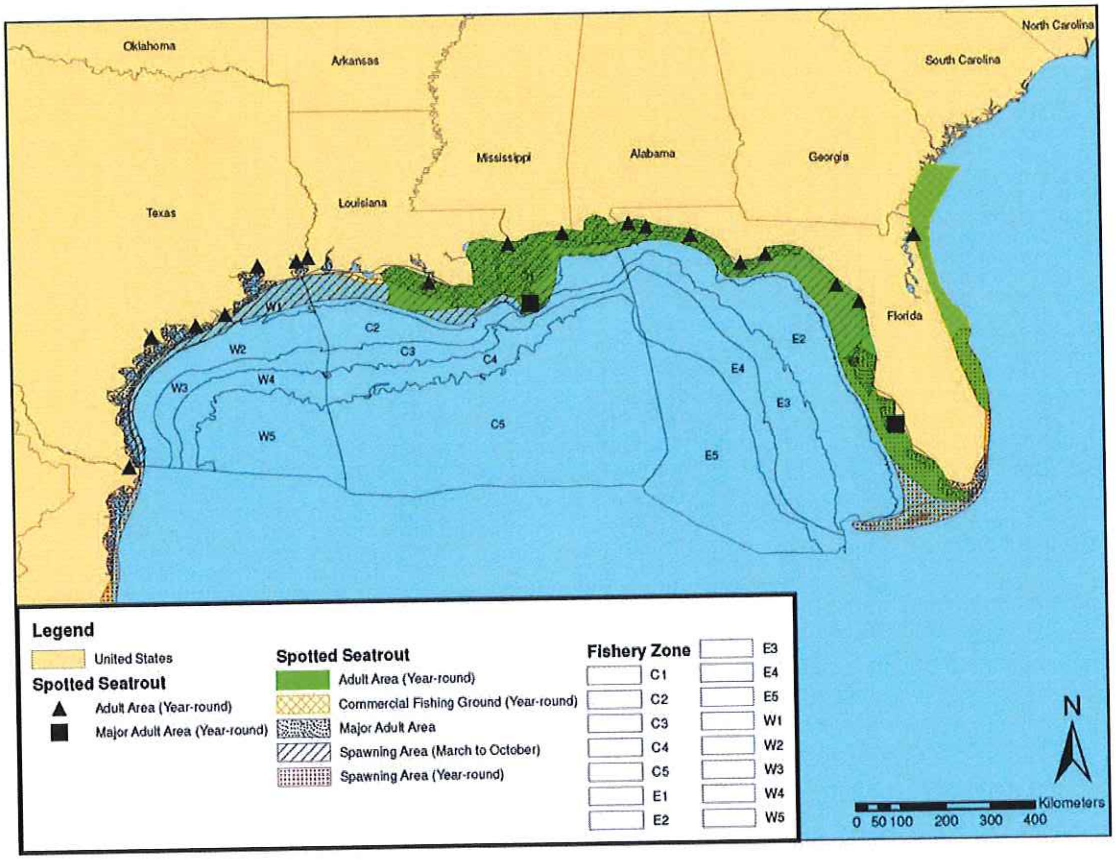


Figure 21. Distribution of spotted seatrout in the GOM. Source: NOAA (1985).

Spotted seatrout are most common in the shallow bays during spring and summer. As water temperatures decline during fall, fish move into deeper bay waters and the GOM. As water temperatures warm in the spring the fish move back into the shallows of the primary and secondary bays (TPWD 2008). Spotted seatrout reaches sexual maturity at one to two years. A female spotted seatrout may spawn several times during the season. Younger females may release 100,000 eggs and older, larger females may release a million eggs (TPWD 2008). Spawning occurs within estuaries and offshore to depths of only 3-4 m (Lassuy 1983c). They prefer shallow grassy areas where eggs and larvae have some cover from predators.

Based upon future development projections, no CWIS facilities are planned for waters shallower than 200 m (i.e. Zones E1-E3, C1-C3, W1-W3). Because the reproductive activities of spotted seatrout are associated with shallow nearshore estuarine waters of the Gulf inside the 20 m isobath, entrainment by offshore CWIS is not an issue for this species.

## Sheepshead (*Archosargus probatocephalus*)
## Rank 3: (Recreational Fishery)

The sheepshead occurs along the coast and in estuaries and brackish water throughout the GOM (McEachran and Fechhelm 2005. This species ranks 3rd in the GOM recreational fisheries, excluding Texas, with over 4.5 million pounds landed annually (1.7 million fish). An additional 74,000 fish are taken each year in Texas. Commercially, sheepshead rank 36th with about $671,000 in annual landings totaling in excess of 2.0 million pounds.

The euryhaline sheepshead prefers brackish waters and can be found inshore around rock pilings, jetties, mangrove roots, and piers as well as in tidal creeks (FLMNH 2008b). It seeks out warmer spots near spring outlets and river discharges and sometimes enters freshwater during the winter months. This fish moves to offshore areas in later winter and early spring for spawning, which sometimes occurs over artificial reefs and navigation markers. Juveniles live in seagrass flats and over mud bottoms.

In the GOM spawning occurs primarily from January through May (FLMNH 2008b). Adults migrate to offshore waters to spawn, later returning to nearshore waters and estuaries. Spawning frequency ranges from once a day to once every 20 days. Little is known regarding spawning behavior. Females may produce from 1,100 to 250,000 eggs per spawning event (FLMNH 2008b). One study determined that those fishes found closer to shore averaged 11,000 eggs per spawning event while those offshore averaged 87,000 eggs per batch. The buoyant eggs are approximately 0.8 mm in diameter and hatch in 28 hours following fertilization at 23°C (FLMNH 2008b).

Although sheepshead move offshore to spawn the distances involved are likely not great. In the entire SEAMAP database, there are only five recorded quantitative plankton tows that have taken either *Archosargus probatocephalus* or *Archosargus* sp. Densities ranged from 0.01 to 0.07 larvae/$m^3$ and were taken over a depth range of 15 to 35 m.

Based upon future development projections, no CWIS facilities are planned for waters shallower than 200 m (i.e. Zones E1-E3, C1-C3, W1-W3). Because the reproductive activities of sheepshead are associated with very shallow nearshore estuarine waters of the Gulf inside the 35 m isobath, entrainment by offshore CWIS is not an issue for this species.

## Red Snapper (*Lutjanus campechanus*)
## Rank 4: (Recreational Fishery)

See listing under commercial fishery.

## Gag Grouper (*Mycteroperca microlepis*) Rank 5: (Recreational Fishery) And Other Serranidae

The gag grouper belongs to the family Serranidae, which contains groupers, sea bass, and hinds. There are 61 species and 20 genera of Serranidae present in the GOM (McEachran and Fechhelm 2005). Over 3.5 million pounds (483,000 fish) of gag are taken annually in the GOM recreational fishery. No landings are reported for Texas. Gag also ranks 14$^{th}$ in the GOM commercial fishery with over 2.5 million pounds landed annually worth approximately $6.4 million.

Residing in brackish to marine waters, the gag grouper is found offshore on rocky bottom as well as inshore on rocky or grassy bottoms to depths of 152 m. It is common on rocky ledges along the eastern GOM (FLMNH 2008c). All of the six other species of *Mycteroperca* grouper in the GOM occur in coastal waters inside the 150 m isobath (McEachran and Fechhelm 2005).

Gag spawn from January through May in the GOM and the South Atlantic Bight at offshore spawning grounds. There is a major spawning ground on the west Florida Shelf (FLMNH 2008c). As is the case discussed previously for red and other *Epinephelus* grouper, the spawning periods for gag and other *Mycteroperca* grouper do not overlap with the June-November SEAMAP sampling program. During the 26 years for which SEAMAP data is available, representing a total of approximately 7,700 quantitative plankton tows in the northern GOM, *Mycteroperca* spp. (seven species combined) larvae have been reported only six times and at an average density of only 0.054 larvae/m$^3$.

Based upon future development projections, no CWIS facilities are planned for waters shallower than 200 m (i.e. Zones E1-E3, C1-C3, W1-W3). Because gag are associated with shallow nearshore waters of the Gulf inside the 152 m isobath, entrainment by offshore CWIS is not an issue for this species.

**Spanish Mackerel (*Scomberomorus maculatus*)/**
**King Mackerel (*S. cavalla*)**
**Rank 6 and 7: (Recreational Fishery)**

The king mackerel is found along the western coast of the Atlantic Ocean from Massachusetts to Rio de Janeiro, Brazil and the GOM (Figure 22). The Atlantic Ocean and GOM stocks mix in south Florida waters (FLMNH 2008d).

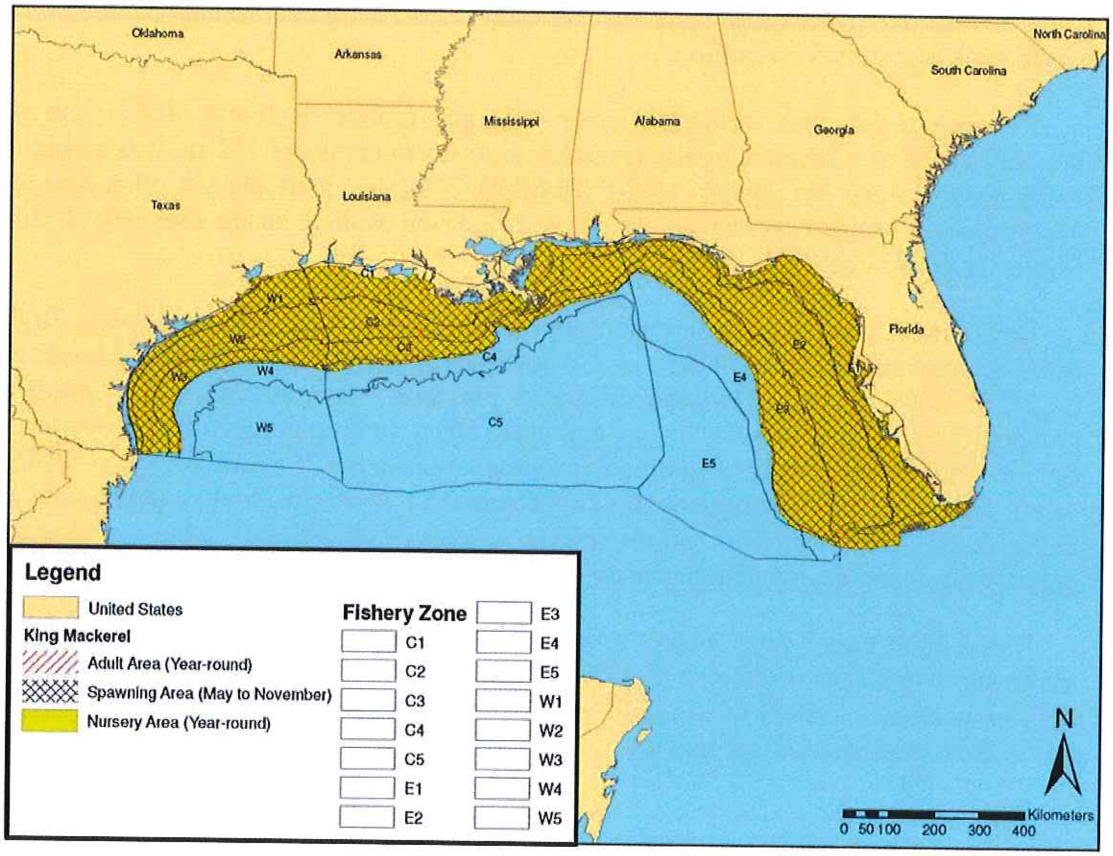


Figure 22. Distribution of king mackerel in the GOM. Source: NOAA (1985).

The king mackerel ranks 7th in the GOM recreational fishery with nearly 2.7 million pounds (310,000 fish) landed annually. Approximately 96% of annual catch by weight occurs off Alabama (25%) and western Florida (71%). An additional 20,000 fish are landed annually in Texas waters. The species ranks 24th in the GOM commercial fishery with annual landings worth $1.2 million. The king and cero mackerel complex is worth an additional $1.5 million (reported together by NMFS 2008a). The majority of commercial landing occur off Louisiana and western Florida.

The king mackerel is a pelagic fish that is found from the shore out to 200 m depths (NOAA 1985). Large schools in the northern hemisphere migrate northward during vernal warming and southward during autumnal cooling (McEachran and Fechhelm 2005). King mackerel migrate from south Florida to the northern GOM in spring, and back again in fall

(NOAA 1985). Resident populations may exist off Louisiana and Florida (McEachran and Fechhelm 2005).

Little is known about the reproduction of king mackerel (FLMNH 2008d). In the GOM, spawning occurs most frequently during May through September. Eggs are believed to be released and fertilized continuously during these months, with a peak between late May and early July with another between late July and early August.

The Spanish mackerel is a pelagic species found throughout the GOM in estuaries and on the continental shelf to depths of 100 m (Figure 23, NOAA 1985).

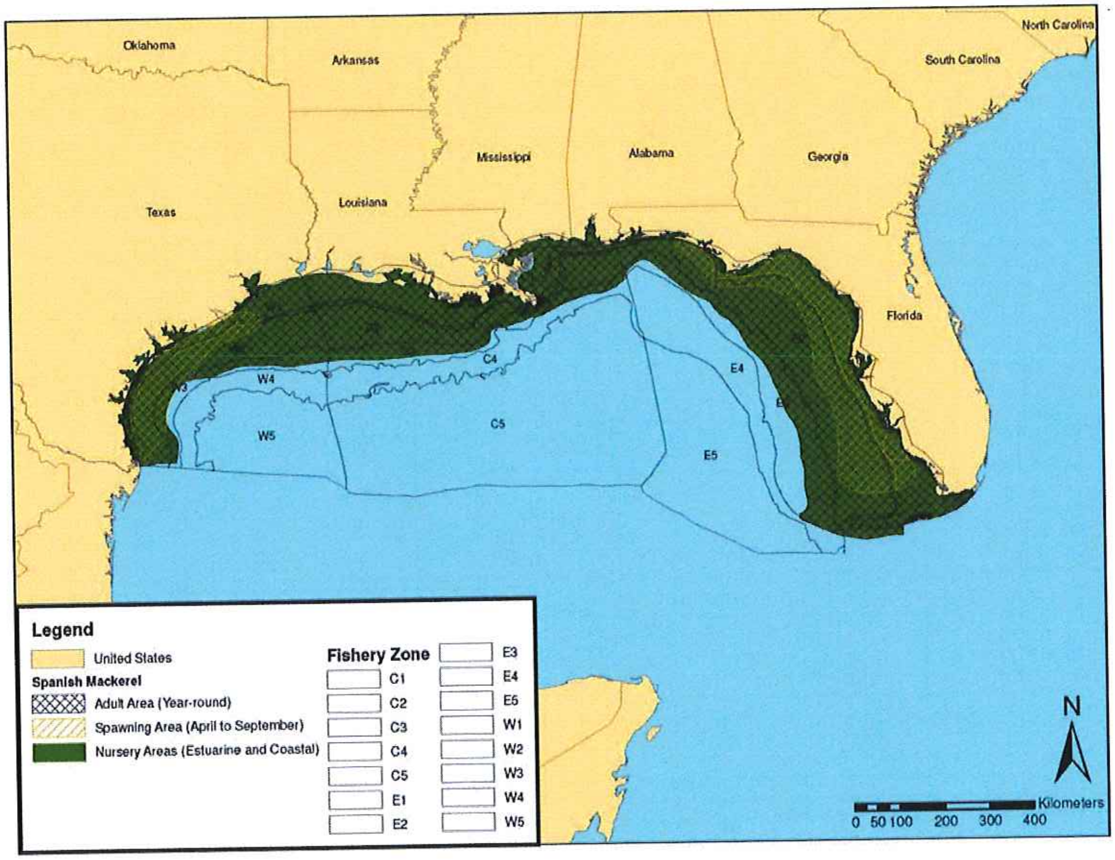


Figure 23. Distribution of Spanish mackerel in the GOM. Source: NOAA (1985).

The Spanish mackerel ranks 6th in the GOM recreational fishery with over 2.7 million pounds (1.8 million fish) landed annually. Over 96% of landings are from Alabama (9%) and western Florida (87%) waters. Only 6,000 fish are taken each year in Texas waters. The commercial fishery for Spanish mackerel is relatively small with annual landings worth $732,000 (1.3 million pounds). Commercial landings occur almost entirely off Alabama (58) and western Florida (41).

Like king mackerel, Spanish mackerel move from south Florida into the northeast GOM in spring and return to Florida in the fall (NOAA 1985). In the GOM Spanish mackerel spawn offshore over a protracted season from April to September (Godcharles and Murphy 1986). Spawning is believed to occur at night and more than once a season.

King and Spanish mackerel are discussed together because the literature search could not compile a complete suite of life history parameter values for either species. Daily natural mortality rates and stage duration rates for larvae have been reported for both species (see Tables 8 and 9). Natural mortality rates for eggs have been reported for neither (see Table 6). Egg duration times have been reported for Spanish mackerel but not for king mackerel (see Table 7).

## Black Drum (*Pogonias cromis*)
## Rank 8: (Recreational Fishery)

The black drum is distributed throughout coastal and estuarine waters of the GOM from Florida to the Yucatan but is most abundant in Louisiana, Texas, and northern Mexico (Figure 24, NOAA 1985). Annual commercial landings average 5.0 million pounds yielding nearly \$3.6 million. Landings are limited primarily to Louisiana (49%) and Texas (50%). In terms of dollar value, the black drum ranks 16th in the Gulf commercial fishery. Commercial fisheries operate largely in estuaries and bays but in Louisiana fishing may occur in coastal waters within the 20 m isobath (NOAA 1985). Recreational fisheries (FL, AL, MS, LA) take approximately 2.6 million pounds (581,000 fish) of black drum annually with another 79,000 taken in Texas waters. Black drum rank 8th in recreational landings by weight in the GOM. Over 78% of the recreational take is from Louisiana waters.

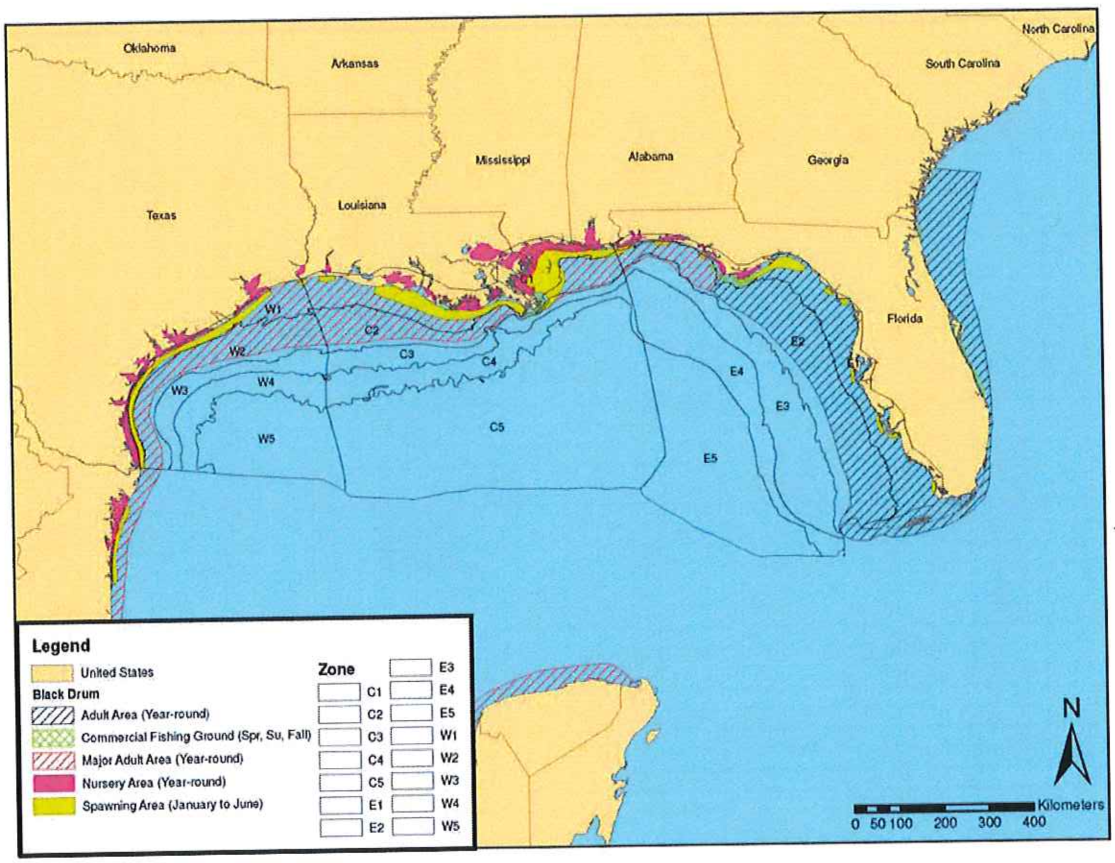


Figure 24. Distribution of black drum in the GOM. Source: NOAA (1985).

Adult black drum are primarily an estuarine species (Hoese and Moore 1998) but have been taken out to a depth of 27 m and occasionally to 37 m (Ross et al. 1983, Cody et al. 1985). They spawn in or near coastal passes and in open bays and estuaries (Sutter et al. 1986) well within the 20-m isobath.

Based upon future development projections, no CWIS facilities are planned for waters shallower than 200 m (i.e. Zones E1-E3, C1-C3, W1-W3). Because the reproductive activities of black drum are associated with shallow nearshore estuarine waters of the Gulf inside the 20 m isobath, entrainment by offshore CWIS is not an issue for this species.

## Dolphinfish (*Coryphaena hippurus*)
## Rank 9: (Recreational Fishery)

The dolphinfish occurs worldwide in tropical and warm temperate seas in both oceanic and coastal waters (Figure 25, McEachran and Fechhelm 2005). The dolphinfish ranks 9th in the recreational fishery with 2.3 million pounds (373,000 fish) landed annually. Only about 4,200 fish are taken in Texas waters.

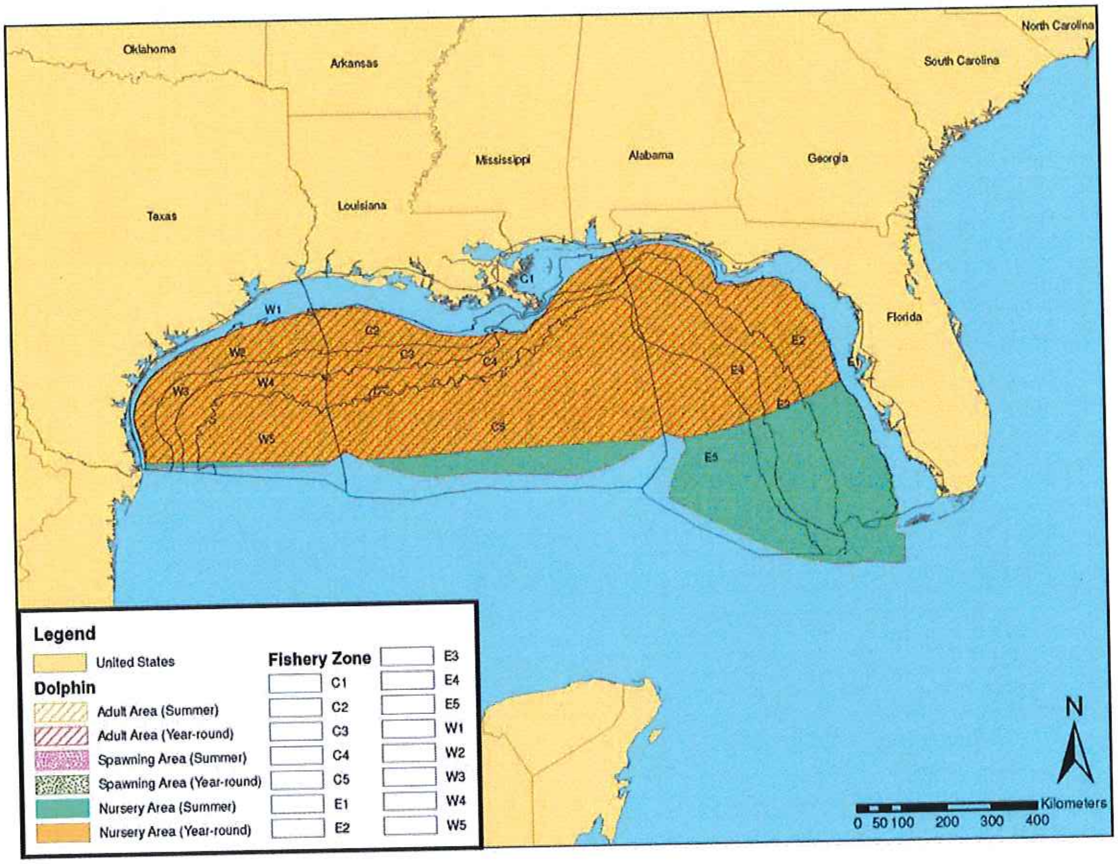


Figure 25. Distribution of dolphinfish in the GOM. Source: NOAA (1985).

In pelagic regions, *Coryphaena hippurus* is commonly found near floating objects apparently because its prey seek refuge under and within the flotsam (Palko, et al. 1982). The dolphinfish is a relatively short-lived fish and are believed to live an average of two years, and a maximum of five years (Beardsley, 1967). Females may spawn two to three times per year and produce between 80,000 and 1,000,000 eggs per event. In waters above 34° C, larvae are found all year, with greater numbers detected in spring and fall. In one study, 70% of the youngest larvae collected in the northern GOM were found at depths greater than 180 meters (Ditty et al. 1994).

A full suite of life-history parameters has not yet been compiled for this species.

## Other Fishes
## Rank 10: (Recreational Fishery)

The generic category "Other Fishes" ranks 10th in GOM recreational fisheries in terms of weight Over 1.9 million pounds are landed annual in the GOM (ex Texas). This represents close to 1.6 million fish. Another 193,000 fish are landed in Texas. No CWIS entrainment assessment can be made for this category.

## Anchovies (Engraulidae)
## (Forage Fish)

Five species of anchovy have been confirmed to occur in the northern GOM and more southerly species may temporarily move north under proper oceanographic conditions (Hoese and Moore 1998, McEachran and Fechhelm 1998). The bay anchovy (*Anchoa mitchilli*) and striped anchovy (*A. hepsetus*) are the most common species in the waters of the northern Gulf (Hoese and Moore 1998). The bay anchovy is restricted to bays, inshore areas, and coastal fresh to brackish waters. The striped anchovy is usually found farther offshore than the bay anchovy. Fertilized eggs and larvae of all anchovy are pelagic. Excluding small fisheries operating off the southern west coast of Florida, there are no commercial or recreational fisheries for any anchovy species in the GOM (NMFS 2008a). No species of sardine are reported in the NMFS Fisheries Statistics Division ST1 and TDPW recreational fishery databases. Nevertheless, anchovies are considered to be an integral component of the forage fish community.

In the GOM, seawater entrainment assessments associated with planned LNG facilities have used the bay anchovy as a proxy species representative of all Engraulid taxa in the Gulf (TORP 2006; USCG and MARAD 2005a, 2005b, 2006a, 2006b). Because anchovies are not taken commercially or recreationally, entrainment losses have been evaluated based upon total numbers of age-1 anchovies (all species combined) lost to entrainment relative to the total forage fish population in the GOM (TORP 2006; USCG and MARAD 2005a, 2005b, 2006a, 2006b).

### Life Stages, Daily Instantaneous Mortality, Stage Duration

e$^2$M (2005) first derived life-history parameter values based upon references to relevant scientific literature (Appendix Table D9). We know of no information that would improve on those estimates and will use them for CWIS entrainment analyses. The original e$^2$M (2005) life-history parameter values for bay anchovy have been used in all of the LNG entrainment analyses in the GOM to date (e.g., TORP 2006; USCG and MARAD 2005a, 2005b, 2006a, 2006b).

### Assessment

In the GOM, Engraulids spawn throughout the year with peak spawning occurring from March through September (Ditty et al. 1988). Because SEAMAP sampling is conducted primarily during the months of June through November there are no adequate SEAMAP estimates of larval densities for the period December-May. To address this issue, USCG and MARAD (2004), as amended by USCG and MARAD (2005) developed an approach to CWIS Engraulid entrainment based upon monthly abundance data collected by Ditty (1986) offshore Louisiana.

Ditty (1986) reported that the average monthly density of Engraulid larvae in the neritic (continental shelf) waters of the Northern Gulf of Mexico for the period December-May ranged from 1.6 to 193.8 larvae/100m$^3$ with a period average of 55.3 larvae/100m$^3$ (Table 26). For the period June-November, average monthly densities ranged from 0.8 to 598.1

larvae/100m$^3$ with a period average of 141.0 larvae/100m$^3$. The ratio of the average larval density from December-May to the average larval density for June through December yielded a comparative ratio of 0.3922. This ratio is used to estimate Engraulids density in the GOM for the period December-May when no SEAMAP sampling occurs: average larval density for December-May equals 0.3922 times the observed average larval density for the period June-November.

Table 27 lists all Engraulid taxa reported in the SEAMAP database. In the vast majority of instances, larvae are identified only to the level of family. For each of the ichthyoplankton tows in the SEAMAP database in which Engraulid taxa were present, all taxa were incorporated into a single density value. For example, for any single tow, if the reported density of Engraulidae was $x$ larvae/m$^3$, and the density of *Anchoa* spp. was $y$ larvae/m$^3$, and the density of *Engraulis eurystole* was $z$ larvae/m$^3$ (assume only three taxon reported), then the density of Engraulids for that tow would be $x + y + z$ larvae/m$^3$.

Table 26. Reported average monthly densities (number/100 m$^3$) of Engraulids reported by Ditty (1986).

| Dec | Jan | Feb | Apr | May | | Average |
|---|---|---|---|---|---|---|
| 4.0 | 1.6 | 2.9 | 193.8 | 74.3 | | 55.3 |
| | | | | | | |
| Jun | Jul | Aug | Sep | Oct | Nov | Average |
| 598.1 | 213.4 | 3.0 | 27.6 | 3.3 | 0.8 | 141.0 |
| | | | | | | |
| Ratio of December-May to June-November = | | | | | | 0.3922 |

Table 27. Engraulid taxa reported in the SEAMAP database.

| Taxon | Common Name | Tows |
|---|---|---|
| Engraulidae | | 3387 |
| Anchoa spp. | | 161 |
| *Anchoa hepsetus* | Striped anchovy | 31 |
| *Anchoa mitchilli* | Bay anchovy | 11 |
| *Anchoa lyolepis* | Dusky anchovy | 4 |
| *Engraulis eurystole* | Silver anchovy | 60 |
| *Anchoviella* sp.[1] | | 2 |
| *Anchoviella perfasciatus* | Flat anchovy | 3 |

[1] Because there is only one species of *Anchoviella*, all *Anchoviella* sp. are actually *A. perfasiatus*.

Table 28 lists the larval densities of Engraulids (± 95% CI) as derived from the SEAMAP database for the period June-November and projected daily seawater usage by zone. Daily entrainment is calculated for each zone by multiplying density times daily water usage rate to yield daily entrainment. Daily entrainment rates are multiplied times the exposure period of 182 days (June-November) to yield entrainment. Table 29 lists the larval densities for the period December-May and projected daily seawater usage. Daily entrainment is calculated for each zone by multiplying density times daily water usage rate to yield daily entrainment. Total entrainment is calculated by multiplying daily entrainment rates times the exposure period of 183 days (December-May) and by the seasonal ratio 0.3922 derived from Ditty (1986). Total entrainment for each season is then summed across all zones to obtain total annual entrainment Table 30.

Table 28. SEAMAP larval densities (± 95% CI) for Engraulids for the period June-November and daily seawater usage estimates by zone. Daily entrainment is calculated by multiplying density times daily water usage rate to yield daily entrainment. Daily entrainment rates are multiplied times the exposure period of 182 days (June-November) to yield total entrainment. Shaded area denoted the only zones where future CWIS activity is projected.

| Zone | Larval Density (no./m3) | | | Water Usage (Million m3/day) | Daily Entrainment | | | Total Entrainment (Millions) Over 182 Days of Exposure | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | LCL | UCL | | Mean | LCL | UCL | Mean | LCL | UCL |
| E1 | 2.3676 | 1.4159 | 3.3194 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E2 | 0.3964 | 0.2395 | 0.5533 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E3 | 0.1000 | 0.0581 | 0.1420 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E4 | 0.0484 | 0.0027 | 0.0940 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E5 | 0.0043 | 0.0000 | 0.0099 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C1 | 9.8733 | 7.1066 | 12.6400 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C2 | 3.9281 | 3.1459 | 4.7103 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C3 | 0.4901 | 0.3592 | 0.6211 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C4 | 0.3335 | 0.1639 | 0.5031 | 0.05678 | 18,935 | 9,304 | 28,565 | 3.446 | 1.693 | 5.199 |
| C5 | 0.0468 | 0.0000 | 0.0973 | 0.91986 | 43,082 | 0 | 89,465 | 7.841 | 0 | 16.283 |
| W1 | 3.9846 | 2.8131 | 5.1561 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| W2 | 6.0124 | 3.2330 | 8.7918 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| W3 | 0.7518 | 0.5680 | 0.9356 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| W4 | 0.1045 | 0.0666 | 0.1424 | 0.01514 | 1,583 | 1,008 | 2,157 | 0.288 | 0.184 | 0.393 |
| W5 | 0.0542 | 0.0000 | 0.1121 | 0.17791 | 9,643 | 0 | 19,937 | 1.755 | 0 | 3.629 |

Table 29. SEAMAP larval densities (± 95% CI) for Engraulids covering the period December-May and seawater usage estimates by zone. Daily entrainment is calculated by multiplying density times daily water usage rate to yield daily entrainment. Daily entrainment rates are multiplied times the exposure period of 183 days (December-May) and by the seasonal ratio 0.3922 derived from Ditty (1986) to yield total entrainment. Shaded area denoted the only zones where future CWIS activity is projected.

| Zone | Larval Density (no./m3) | | | Water Usage (Million m3/day) | Daily Entrainment (Millions) | | | Total Entrainment (Millions) Over 183 Days of Exposure | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | LCL | UCL | | Mean | LCL | UCL | Mean | LCL | UCL |
| E1 | 2.3676 | 1.4159 | 3.3194 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E2 | 0.3964 | 0.2395 | 0.5533 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E3 | 0.1000 | 0.0581 | 0.1420 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E4 | 0.0484 | 0.0027 | 0.0940 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E5 | 0.0043 | 0.0000 | 0.0099 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C1 | 9.8733 | 7.1066 | 12.6400 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C2 | 3.9281 | 3.1459 | 4.7103 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C3 | 0.4901 | 0.3592 | 0.6211 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C4 | 0.3335 | 0.1639 | 0.5031 | 0.05678 | 18,935 | 9,304 | 28,565 | 1.359 | 0.668 | 2.050 |
| C5 | 0.0468 | 0.0000 | 0.0973 | 0.91986 | 43,082 | 0 | 89,465 | 3.092 | 0 | 6.421 |
| W1 | 3.9846 | 2.8131 | 5.1561 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| W2 | 6.0124 | 3.2330 | 8.7918 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| W3 | 0.7518 | 0.5680 | 0.9356 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| W4 | 0.1045 | 0.0666 | 0.1424 | 0.01514 | 1,583 | 1,008 | 2,157 | 0.114 | 0.072 | 0.155 |
| W5 | 0.0542 | 0.0000 | 0.1121 | 0.17791 | 9,643 | 0 | 19,937 | 0.692 | 0 | 1.431 |

Table 30. Estimated annual entrainment of Engraulid larvae and eggs. Values are derived by multiplying Engraulid larval density times the egg to total larvae ratio.

| Component | Total Entrainment Over 365 Days of Exposure | | |
|---|---|---|---|
| | Mean | LCL | UCL |
| Larval Entrainment | 18,587,085 | 2,617,106 | 35,559,435 |
| Egg/Larval Ratio | 0.3315 | 0.3315 | 0.3315 |
| Egg Entrainment | 6,161,619 | 867,571 | 11,787,953 |

The egg ratio was calculated by dividing total average egg density across Zones C4, C5, W4, and W5 by average total larval density (all taxa) across Zones C4, C5, W4, and W5. The ratio for this case was 0.3315. This ratio was multiplied times total Engraulid entrainment to yield total Engraulid egg entrainment. (see Table 30).

The number of age-1 equivalents was then calculated for the base, high-mortality, and low-mortality life history values as described in Appendix Table D9 using the method and data presentation format described by e$^2$M (2005) (Tables 31-33). The number of age-1 equivalents represents the number of anchovy eggs and larvae lost to entrainment that would have otherwise survived natural mortality during the first year of life (i.e., reached the age of 1). The number of age-1 equivalents is then compared to the total forage fish population in the GOM to determine the proportionate loss attributed to CWIS entrainment (TORP 2006; USCG and MARAD 2005a, 2005b, 2006a, 2006b).

Table 31. Age-1 equivalents for Engraulids using base life-history mortality estimates across all life stages.

| Stage | Instantaneous Mortality | Duration (Days) | Natural Mortality per Stage | Fishing Mortality per Stage | Total Mortality per Stage | Fraction Surviving | Correction |
|---|---|---|---|---|---|---|---|
| Egg | 1.044 | 1 | 1.0440 | 0 | 1.0440 | 0.3520 | 0.52076 |
| Larvae | 0.2059 | 34 | 7.0006 | 0 | 7.0006 | 0.0009 | 0.00182 |
| Juvenile | 0.004 | 330 | 1.3035 | 0 | 1.3035 | 0.2716 | |
| | Total = | 365 | | Total = | 9.3481 | | |

| Stage | Number Potentially Entrained | | | Fraction Surviving to Age 1 | Number Surviving to Age 1+ | | |
|---|---|---|---|---|---|---|---|
| | LCL | Mean | UCL | | LCL | Mean | UCL |
| Egg | 2,617,106 | 18,587,085 | 35,559,435 | 0.000129 | 337 | 2,396 | 4,583 |
| Larvae | 867,571 | 6,161,619 | 11,787,953 | 0.000495 | 429 | 3,047 | 5,830 |
| Juvenile | | | | | | | |
| | | | | Total = | 766 | 5,443 | 10,413 |

Table 32. Age-1 equivalents for Engraulids using low mortality estimates across all life stages.

| Stage | Instantaneous Mortality | Duration (Days) | Natural Mortality per Stage | Fishing Mortality per Stage | Total Mortality per Stage | Fraction Surviving | Correction |
|---|---|---|---|---|---|---|---|
| Egg | 0.69 | 1 | 0.6900 | 0 | 0.6900 | 0.5016 | 0.66807 |
| Larvae | 0.1804 | 30.63 | 5.5257 | 0 | 5.5257 | 0.0040 | 0.00793 |
| Juvenile | 0.004 | 333.4 | 1.3336 | 0 | 1.3336 | 0.2635 | |
| | Total = | 365 | | Total = | 7.549252 | | |

| Stage | Number Potentially Entrained | | | Fraction Surviving to Age 1+ | Number Surviving to Age 1+ | | |
|---|---|---|---|---|---|---|---|
| | LCL | Mean | UCL | | LCL | Mean | UCL |
| Egg | 2,617,106 | 18,587,085 | 35,559,435 | 0.000701 | 1,835 | 13,035 | 24,937 |
| Larvae | 867,571 | 6,161,619 | 11,787,953 | 0.002091 | 1,814 | 12,884 | 24,649 |
| Juvenile | | | | | | | |
| | | | | Total = | 3,649 | 25,919 | 49,586 |

Table 33. Age-1 equivalents for Engraulids using high mortality estimates across all life stages

| Stage | Instantaneous Mortality | Duration (Days) | Natural Mortality per Stage | Fishing Mortality per Stage | Total Mortality per Stage | Fraction Surviving | Correction |
|---|---|---|---|---|---|---|---|
| Egg | 1.94 | 1 | 1.9400 | 0 | 1.9400 | 0.1437 | 0.25130 |
| Larvae | 0.231 | 34 | 7.8540 | 0 | 7.8540 | 0.0004 | 0.00078 |
| Juvenile | 0.01 | 330 | 3.3000 | 0 | 3.3000 | 0.0369 | |
| | Total = | 365 | | Total = | 13.094 | | |

| Stage | Number Potentially Entrained | | | Fraction Surviving to Age 1+ | Number Surviving to Age 1+ | | |
|---|---|---|---|---|---|---|---|
| | LCL | Mean | UCL | | LCL | Mean | UCL |
| Egg | 2,617,106 | 18,587,085 | 35,559,435 | 0.000004 | 9 | 67 | 128 |
| Larvae | 867,571 | 6,161,619 | 11,787,953 | 0.000029 | 25 | 176 | 337 |
| Juvenile | | | | | | | |
| | | | | Total = | 34 | 243 | 465 |

The age-1 tables above were presented to maintain continuity with previous LNG assessments in the GOM (USCG and MARAD 2003, 2004, 2005a, 2005b, 2006a, 2006b; TORP 2006). Conceptually, using high mortality life-history values instills greater natural mortality on eggs and larvae. The number of age-1 equivalents lost to entrainment is less because a higher proportion of those eggs and larvae would have been lost to natural mortality anyway. Conversely, using low mortality life-history values instills lower natural mortality on eggs and larvae. The estimated number of age-1 equivalents lost to entrainment is higher for lower mortality life history data because a lower proportion of those eggs and larvae would have been lost to natural mortality in the first place

We suggest that the use of low- and high-mortality life-history estimates may be misleading and exaggerates projected impacts of CWIS entrainment. In the low mortality case (see Table 32), the two worst-case extremes (lowest natural mortality rate, lowest stage duration) are used multiplicatively. Natural mortality ($d^{-1}$) times stage duration in days yield stage mortality. The lower the stage mortality the higher the proportion of entrained larvae (or eggs) that are considered lost to the environment as a direct impact of the CWIS entrainment. In the cases above, lowering $M$ from 0.2059 $d^{-1}$ (base case) to 0.1804 $d^{-1}$ (low mortality case) and simultaneously lowering stage duration from 34 to 30.63 days results in a five-fold increase in the projected number of age-1 equivalents lost to entrainment. That the two worst-case life-history estimates would co-occur naturally is highly problematic. Unless there is direct evidence that such a situation can occur within reasonable expectation, the base case model represents the best scenario for judging the effects of CWIS entrainment.

Lastly, the projected losses of age-1 equivalents was compared to the projected standing stock of forage fish in the GOM. The estimated total biomass of small pelagic species (e.g., forage fish) in the GOM is 5,844,454,571 pounds (USCG 2005). Using a rough estimate of 0.0063273 pounds per forage fish (USCG 2005) yields a population estimate of 923,688,551,357 forage fish in the GOM.

The projected percent loss for the base case, mean entrainment scenario was 5.893 E-7 (Table 34).

Table 34. Projected annual entrainment loss of Engraulids as a percent of GOM forage fish (923,688,551,357).

| Case | LCL | Mean | UCL |
|---|---|---|---|
| Base | 8.297E-08 | 5.893E-07 | 1.127E-06 |
| Low | 3.951E-07 | 2.806E-06 | 5.368E-06 |
| High | 3.708E-09 | 2.633E-08 | 5.038E-08 |

# LITERATURE CITED

This section contains references for all the literature cited in this document. Included are references appearing as tabular entries in Tables 6-9. These tables were largely taken from published reviews with principal authors being cited in the caption. The citations within each table were those provided by the principal author as per the specific publication. Many of these papers were not actually reviewed by LGL in the preparation of this document.

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# APPENDICES

Appendix A. Description of Methods for Analyzing SEAMAP Fish Larvae and Egg Data

Appendix B. Description of Methods for Analyzing SEAMAP Fish and Invertebrate Trawl Data

Appendix C. Gulf of Mexico Newbuild Rigs and Fleet Size Changes.

Appendix D. Life-History Summary Tables

# Appendix A

**Description of Methods for Analyzing SEAMAP Fish Larvae and Egg Data**

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Updated: October 29, 2004

## Data Tables

Three SEAMAP data tables are used together to analyze fish larvae and egg catch rates:

- STATCARD. This data table contains when and where sampling operations take place. Fields relevant to these analyses include (note underscores "_" in field names have been replaced by periods ".":

  1. CRUISE.NO
  2. VESSEL
  3. P.STA.NO
  4. S.LATD
  5. S.LATM
  6. S.LOND
  7. S.LONM
  8. S.STA.NO
  9. MO.DAY.YR

- ICHSTRWK. This data table contains information on the plankton samples taken at each station. It contains all of the egg data. Fields relevant to these analyses are listed below:

  1. CRUISE.NO
  2. VESSEL
  3. P.STA.NO
  4. SAMPLE.NO
  5. GEAR.CODE
  6. MESH.CODE
  7. VOL.FILT
  8. NO.EGGS
  9. EGGS.ALIQUE

- ICHSARWK. This is the individual taxa data table. It contains information on each individual fish larvae taxa collected in each sample. Relevant fields are listed below:

    1. CRUISE.NO
    2. VESSEL
    3. P.STA.NO
    4. SAMPLE.NO
    5. SAMP.STAT
    6. TAXONOMIC
    7. BIOCODE
    8. MEAS
    9. NOT.MEAS
    10. ALIQUOT

## Merging Data Tables

The STATCARD and ICHSTRWK data tables can be merged based on 3 fields, CRUISE.NO, VESSEL, AND P.STA.NO. To further merge the resulting set with the ICHSAR set, the SAMPLE.NO field must be included in the merge key.

## Analysis Steps

The STATCARD data table, with its station time and place information is the core data table for these analyses. The data table is read into a database file (R data.frame), where the station latitude and longitude values are converted to decimal degrees, and the sample date is used to create variables for sampling month and year. Next, the ICHSTRWK data table is read into a database file (R data.frame), and restricted to records with GEAR.CODE equal to 1 and MESH.CODE equal to 3, which represent the .333 m mesh, 60 cm Bongo net. At this time we also convert the value for VOL.FILT from –9 to NA, to adjust for differences in handling of missing data. [The NO>EGGS variable is also adjusted by the size of the EGGS.ALIQU variable, multiplying subsampled aliquots by the appropriate value to set them equal to 1/1 aliquots.]

**Analysis Constraints**. There are no year or month restrictions placed on the station data. Stations were restricted to a somewhat arbitrary rectangle around the proposed site, with the –93.65 and –92.834 degree longitude lines making the vertical sides, and the 29.00 and 29.334 degree latitude lines making the horizontal sides. All stations that were outside of the rectangle were eliminated.

**Data Table Joins**. At this point the station and ichstr data tables were merged using the fields CRUISE.NO, VESSEL, and P.STA.NO as the merge key.

**Egg CPUE**. Number of eggs per cubic meter of water filtered (Egg.cpue) are calculated for each sample in the combined station-ichstr data table where the VOL.FILT variable is greater than zero. The mean Egg.cpue and 2 standard errors are then calculated to produce the mean value with upper and lower confidence intervals.

**Preparing the Fish Larvae Data Table**. The ICHSARWK data table is read into a database file (R data.frame), and is restricted to records containing a SAMP.STAT (sample status) value of either 1 or 2 (the only values valid for quantitative analysis and summaries, David Hanisko, NMFS, pers. comm.). The variables MEAS and NOT.MEAS are adjusted to zero values where value in the record is –9, then they are added together to create the total count variable, which is then adjusted by the ALIQUOT variable factor to represent a whole sample. This database table is then merged with the station-ichstr data table using the four variables, CRUISE.NO, VESSEL, P.STA.NO, and SAMPLE.NO as the merge key.

**Fish Larvae Summary Values**. Total fish larvae catch for each sample is aggregated, and divided by the sample VOL.FILT variable to create the sample catch per cubic meter of water filtered (Fish.cpue). Then the mean Fish.cpue and 2 standard errors are calculated to produce the mean value with upper and lower confidence intervals, both by month of sampling, and for the overall period.

**Fish Larvae Individual Taxa Catch Rates**. Calculating the catch per cubic meter of water filtered for each taxa caught at anytime in the included samples requires construction of a matrix with one record for each taxa for each sampling record (total size of matrix will be number stations X number of taxa). This data table is then merged with the data table created above (station-ichstr-ichsar, which represents taxa actually caught at each sampling station), and all records with missing values are set to a value of zero. The catch rate per cubic meter of water filtered (Taxa.cpue) can now be calculated for each taxa for each station. These data can be summarized to produce the mean cpue for each taxa along with standard errors, so that upper and lower confidence intervals can be provided.

# Appendix B

Description of Methods for Analyzing SEAMAP Fish and Invertebrate Trawl Data

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Updated: February 26, 2009

## Data Tables

Two SEAMAP data tables are used together to analyze fish and invertebrate catch rates:

- GOMTrawlfix. This data table contains when and where sampling operations take place. Fields relevant to these analyses include (note underscores "_" in field names have been replaced by periods ".":

    1. STATIONKEY
    2. VESSEL
    3. CRUISE
    4. STATION
    5. SEAMAP_NUM
    6. DATA_SOURCE
    7. START_DATE
    8. TIME_ZONE
    9. START_TIME
    10. START_LAT_D
    11. START_LAT_M
    12. START_LONG_D
    13. START_LONG_M
    14. START_DEPTH
    15. END_TIME
    16. END_LAT_D
    17. END_LAT_M
    18. END_DEPTH
    19. GEAR_CODES
    20. SURFACE_TEMP
    21. BOTTOM_TEMP
    22. AIR_TEMP
    23. BAROMETRIC_PRESSURE
    24. WIND_SPEED
    25. WIND_DIRECTION
    26. WAVE_HEIGHT

27. SEA_CONDITION
28. VESSEL_SPEED
29. SHRIMP_STATION
30. TOW_NUMBER
31. NET_NUMBER
32. GEAR_TYPE
33. GEAR_SIZE
34. MESH_SIZE
35. MINUTES_FISHED
36. WATER_COLOR
37. BOTTOM_TYPE

- GOMCatchnoq. This data table contains information on the plankton samples taken at each station. It contains all of the egg data. Fields relevant to these analyses are listed below:

    1. CATCHKEY
    2. STATIONKEY
    3. VESSEL
    4. CRUISE
    5. STATION
    6. TAXON
    7. TOTAL_NUMBER
    8. TOTAL_WEIGHT

## Merging Data Tables

The GOMTrawlfix and GOMCatchnoq data tables can be merged based on 3 fields, CRUISE, VESSEL, and STATION. To further merge the resulting set, the STATIONKEY field must be included in the merge key.

## Analysis Steps

The GOMTrawlfix data table, with its station time and place information is the core data table for these analyses. The data table is read into a database file (i.e.,dbf), where the station latitude and longitude values are converted to decimal degrees. The database file is converted to a shapefile for GIS analysis. The records are restricted to VESSEL equal to 4, GEAR_SIZE equal to 40 (feet), and MESH_SIZE equal to 1.63 (mm). Next, the GOMCatchnoq data table is read into a database file (i.e.,dbf) and converted into a GIS shapefile, and restricted to records with Vessel equal top 4 (Oregon II). A 10 minute x 10 minute grid was created to cover the area trawled. MINUTES_FISHED was converted into hours and summed for each 10 minute x 10 minute cell providing trawl effort per cell. TOTAL_NUMBER of individuals was also summed for each cell for each species analyzed. For each species, mean catch per unit Effort (CPUE) was calculated by dividing the sum of the TOTAL_NUMBER of species per cell by the sum of effort trawled (in hours) per cell.

# Appendix C

## Development Scenario for Future Cooling Water Use by New Offshore Facilities in the Gulf of Mexico – Prepared by the Offshore Operators Committee Cooling Water Intake Structure Technical Steering Group

March 2009

# Development Scenario for CWIS Source Water Biological Baseline Characterization Study

**Table of Contents**

## Objective

The objective of the development scenario is to provide the basis for estimating water use from regulated cooling water intake structures apportioned among the set of fishery zones (Figure 1) devised for entrainment assessment. This development scenario document recommends a base case of industry activity for assessment of entrainment by new facilities and also provides data for possible consideration of alternative scenarios.

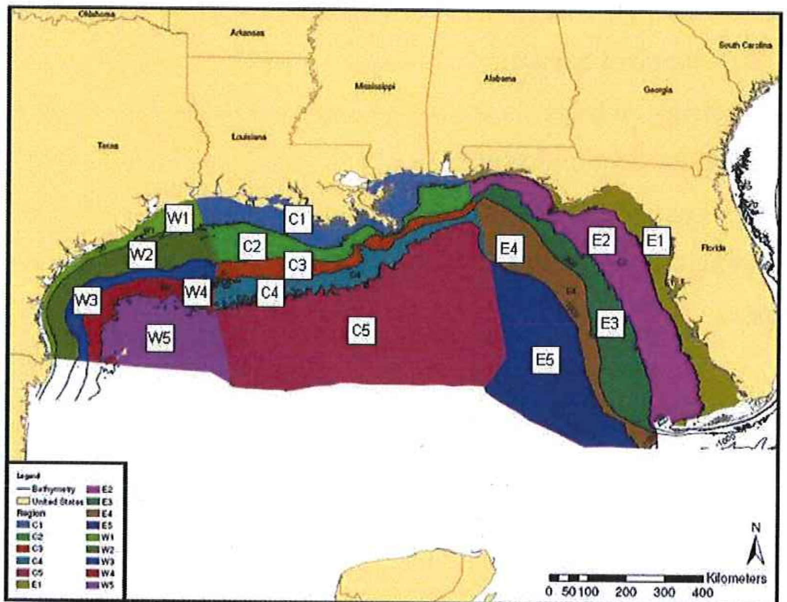



Figure 1. Zones for fishery data and water-use assessment. The depth limits of the zones 1 through 5 correspond, respectively, to 0-20 m, 20-60 m, 60-200 m , and 200-1000 m, and >1000 m (deep GOM).

## Recommended Base Case Development Scenario

Data on the average intake flow rates of various facilities and estimates of the intensity and geographic distribution of industry activity were used to prepare a recommended base case scenario for the estimation of additional seawater intake by regulated facilities (Table 1) that would begin operation by the end of 2011. This time period was chosen so that only integer numbers of facilities would have to be considered.

The remainder of this document discusses the data and rationale used to develop the base case development scenario.

Table 1. Base Case Seawater Use Scenario – Additional Water Use 2009-2011

| Fishery Zone | Production Facilities | | Drill Ships | | Semisubmersible MODU | | Jackup MODU | |
|---|---|---|---|---|---|---|---|---|
| | Number | Total Water Use (MGD) | Number | Total Water Use (MGD) | Number | Total Water Use (MGD) | Number | Total Water Use (MGD) |
| C1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C4 | 2 | 7 | 0 | 0 | 1 | 8 | 0 | 0 |
| C5 | 5 | 55 | 5 | 180 | 1 | 8 | 0 | 0 |
| E1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| W1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| W2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| W3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| W4 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| W5 | 1 | 11 | 1 | 36 | 0 | 0 | 0 | 0 |

## Geographic Distribution of Industry Activity

Since drilling or production activities must take place in leased areas, the distribution of active leases will provide the base case information for the distribution of industry activity in the various fishery zones. A count of the active leases (Table 2) shows that leasing activity is concentrated in the Central and Western fishery zones, with the deeper water zones (W3-W5 and C3-C5) accounting for 65% of the total leased blocks.

Table 2. Distribution of Leases in the Fishery Data Zones in the Gulf of Mexico

| Fishery Data Zones | Number of Total Lease Blocks (Active and Non-Active) | Number of Active Lease Blocks | Fraction of Active Leases (%) |
|---|---|---|---|
| Outside fishery Zones | 73 | | |
| C1 | 1312 | 1016 | 12.9 |
| C2 | 1608 | 950 | 12.1 |
| C3 | 1100 | 668 | 8.5 |
| C4 | 1381 | 926 | 11.7 |
| C5 | 7192 | 2390 | 30.3 |
| E1 | 1144 | 0 | 0.0 |
| E2 | 3092 | 26 | 0.3 |
| E3 | 2131 | 11 | 0.1 |
| E4 | 1801 | 52 | 0.7 |
| E5 | 3140 | 28 | 0.4 |
| W1 | 406 | 212 | 2.7 |
| W2 | 1414 | 433 | 5.5 |
| W3 | 792 | 163 | 2.1 |
| W4 | 859 | 301 | 3.8 |
| W5 | 1645 | 707 | 9.0 |

## Water Use By Drilling Rigs and Production Facilities

Data on water use by offshore facilities was collected from comments submitted during the Clean Water Act Section 316b Phase III rulemaking and from information submitted by OOC member companies. OOC member companies were asked to submit information on existing production facilities that use more than 2 million gallons per day (MGD) seawater with more that 25% of that used for cooling. The CWIS monitoring requirements apply only to new facilities. Existing facilities are not subject to baseline study or entrainment monitoring requirements. However, information on seawater intake rates was collected to identify facilities that might be used as surrogate (i.e. surrogate for yet-to-be-built new facilities) study sites for entrainment monitoring as well as to characterize seawater intake rates for larger production facilities. The information from both these sources is summarized in Table 3. In the few cases where companies provided information on both maximum and typical daily intake volumes, the typical intake volume was used. Data on production platforms should be considered to be representative only of large offshore production facilities.

Table 3. Seawater Intake Rates for Drilling Rigs and Large Production Facilities

| Facility Type | Facility Count for Intake Data | Seawater Intake Rate (MGD) | | | |
|---|---|---|---|---|---|
| | | Median | Min | Max | Avg |
| Production Platform | 44 | 4.6 | 0.0 | 58.4 | 6.3 |
| Jackup Drill Rig | 24 | 6.8 | 4.2 | 9.2 | 6.5 |
| Semisubmersible Drill Rig | 11 | 6.8 | 0.9 | 18.0 | 7.7 |
| Drill Ship | 6 | 40.1 | 10.0 | 52.0 | 36.1 |

## Geographic Distribution of Production Facilities

Production facility seawater intake data submitted by OOC Member Companies show that although facilities using >2 MGD of seawater can be found in any depth range, facilities are found predominantly (75%) in waters > 200m deep (Table 4). Seawater intakes using >5 MGD are only found in waters >200 m deep. These data are consistent with the expectation that new facilities with large cooling water intakes will be constructed mainly in deeper waters, where the cost of structures provides a strong motivation for the use of hub facilities that process oil and gas from a number of fields. All current production facilities are located in the Western and Central fishery data zones.

Table 4. Distribution of Production Facility Seawater Intakes by Fishery Zone Depth

| Fishery Zone Depth (m) | Production Facilities | | Production Facility Seawater Intake Rates (MGD) | | | |
|---|---|---|---|---|---|---|
| | Number | Facilities | Median Usage (mgd) | Average (mgd) | min | max |
| 0-20 | 3 | 0.07 | 1.7 | 1.6 | 0.4 | 2.6 |
| 20-60 | 3 | 0.07 | 0.8 | 2.8 | 0.7 | 6.9 |
| 60-200 | 5 | 0.11 | 1.7 | 2.8 | 0.9 | 5.0 |
| 200-1000 | 16 | 0.36 | 2.8 | 3.5 | 0.3 | 7.2 |
| >1000 | 17 | 0.39 | 6.5 | 11 | 1.9 | 58.4 |

MMS data on production hub facilities, which process fluids from a number of offshore fields, provide another way of looking at the distribution of facilities that are likely to have seawater intakes in the >2 MGD range. Based on MMS data (MMS, 2008) existing hub facilities are concentrated inside the 300 m isobath with new facilities expected 450 – 2300 m depth range (Figure 2, MMS (2008)).

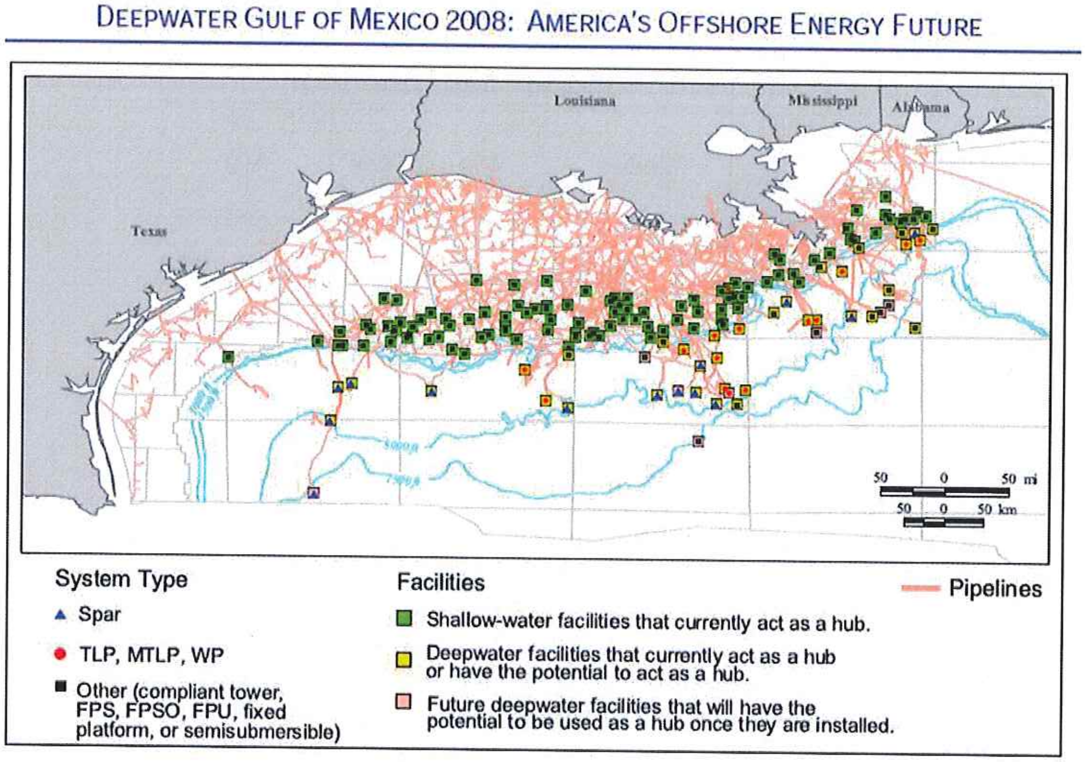



Figure 2. Current and future hub facilities in the Gulf of Mexico (MMS, 2008).

**Number of New Production Facilities Per Year**

New facilities subject to CWIS regulations will be added as new Gulf of Mexico resources are put into production. The number of new production facilities is highly dependent on the economic climate and oil prices both of which have recently deteriorated. For the purposes of entrainment assessment, we will use estimates of new facility installations developed by the Minerals Management Service. Given that industry information about planned new investments is often confidential, the MMS estimates represent the most practical approach to estimating the number of facilities that will start production.

The Minerals Management Service (MMS, 2000) estimated that an average of 2 major deepwater production facilities would be commissioned every year Table 5) .

Table 5. Estimated Startups of Deepwater Production Facilities (MMS, 2000)

| Year | TLP | Spar | Fixed Platform | Total |
|---|---|---|---|---|
| 2000 | 1 | 3 | | 4 |
| 2001 | | 2 | | 2 |
| 2002 | 1 | 1 | 1 | 3 |
| 2003 | 1 | 1 | | 2 |
| 2004 | 1 | | 1 | 2 |
| 2005 | | 1 | | 1 |
| 2006 | | 1 | 1 | 2 |
| 2007 | 1 | | | 1 |

A later study (MMS, 2008) estimated that an average of 7 projects per year would begin production between 2006 and 2013. Considering that not all new fields will result in the installation of separate production facilities, we will conservatively assume a base case of 3 production facilities per year will start operation for a total of 9 by the end of 2011. The locations of the facilities will assigned to depth zones 4 and 5 in proportion to the number of active leases in these zones. The average seawater intake rate for each depth zone (Table 4) will be used as the base case.

**Water Use by Drilling Rigs**

Information on the water depth capabilities of the Gulf of Mexico drilling rig fleet was obtained from the publicly available Rigzone database (www.rigzone.com). Based on this information (Table 6) we can develop water depth assumptions for the operation of different types of drilling rigs. Drillships are assumed to operate only in depth zone 5 (>1000 m). Semisubmersible drilling rigs are assumed to operate in zones 4 and 5. Jackup drilling rigs are assumed to operate in depth zones 2 and 3.

New drilling rigs, i.e. rigs for which construction started after July 17, 2006, that enter the GOM fleet are subject to CWIS requirements. Rigzone was commissioned to query their proprietary database for information concerning the expected delivery of new drilling rigs to the GOM fleet. This query revealed (Appendix A) that by the end of 2011, 7 drillships and 10 semisubmersibles will enter service in the GOM fleet. Six of the drillships and two of the semisubmersibles are subject to CWIS requirements. The Rigzone study concluded that it was unlikely that any new-built jackup drilling rigs would enter the Gulf of Mexico fleet by the end of 2011.

The water use of these rigs was divided among the longitudinal zones (i.e. W, C, and E) in proportion to the number of active leases in each zone (Table 2) subject to the restriction that the number of drilling rigs assigned to a zone must be an integer. None of the eastern (E) depth zones accounts for more than 0.7% of the active lease blocks. As a result, the water use by regulated CWIS on drilling rigs was assumed to be zero for all the E depth zones.

Table 6. Summary of the Gulf of Mexico Drilling Rig Fleet

| Type of Rig | GOM Rig Fleet | | | Water Depth Information (m) | | | |
|---|---|---|---|---|---|---|---|
| | Total # | In Use February 2009 # | Under Construction for GOM (February 2009) # | Current Drilling [b] MIN | Current Drilling [b] MAX | Rating [c] MIN | Rating [c] MAX |
| Jackup | 77 | 45 | 0[a] | 11 | 82 | 38 | 137 |
| Drill Ship | 6 | 6 | 7 | 1271 | 2127 | 3049 | 3049 |
| Semisub | 27 | 24 | 6 | 215 | 2475 | 610 | 3049 |

a. The Rigzone study (Appendix A) concluded that although seven jackups are under construction at U.S. GOM shipyards, all of them are likely to leave the region when they are completed.

b. Current drilling is the depth at which a rig in use in February 2009 was drilling. Based on information in the publicly available Rigzone.com database.

c. Rating is the maximum water depth capability of a drilling rig. Based on information in the publicly available Rigzone.com database.

## References


Richardson, G.E., Nixon, L.D., Bohannon, C., Kazanis, E.G. Montgomery, T.M., Gravois, M.P., (2008); "Deepwater Gulf of Mexico 2008:America's Offshore Energy Future" OCS Report MMS 2008-013 US Minerals Management Service GOM Region http://www.gomr.mms.gov/PDFs/2008/2008-013.pdf

Minerals Management Service Gulf of Mexico OCS Region (2000); "Gulf of Mexico Deepwater Operations and Activities Environmental Assessment" OCS EIS/EA MMS 2000-001 May 2000 https://www.gomr.mms.gov/PDFs/2000/2000-001.pdf

# Appendix

# Gulf of Mexico Newbuild Drilling Rigs and Fleet Size Changes

Prepared by Rigzone.com

March 18, 2009

RigLogix

upstream intelligence system

# Gulf of Mexico

## *Newbuild Rigs and Fleet Size Changes*

**Created March 18, 2009**

This report, commissioned by Offshore Operators Committee (OOC), provides analysis and data regarding changes in the size of the jackup, semisubmersible, and drillship fleets in the Gulf of Mexico, with a focus on newbuild rigs that have and will enter the region during the period 2004 to 2014.

# Introduction and Summary

The National Pollutant Discharge Elimination System (NPDES) permit for the Western and Central Portions of the Gulf of Mexico (EPA, 2007) requires, under the Clean Water Act Section 316 (b) Phase III regulations, that operators of new facilities with cooling water intake structures (CWIS) that take in more than 2 million gallons per day of seawater with more than 25% of that used for cooling water to undertake source water biological baseline surveys. As defined by the permit, a new facility is one for which construction started after July 17, 2006.

The permit provides operators with the choice of either doing individual site-specific studies to meet some of the permit CWIS requirements or participating in a joint industry study, conducted under a plan to be approved by EPA Region 6, aimed at meeting the requirements. The Offshore Operators Committee (OOC) Environmental Sciences Subcommittee (OOC-ESC) has organized the OOC Cooling Water Intake Structure JIP to address CWIS permit requirements through the joint industry study option. The JIP is reviewing drilling rig and production facility data to estimate the number of cooling water intake structures subject to permit requirements and their respective water intake volumes.

OOC contracted with Rigzone to review the proprietary RigLogix database to estimate the number of new drilling rigs that would enter the Gulf of Mexico fleet over the previous five years and in the next five years. The purpose of this review is to provide the basis for predicting cooling water use by drilling rigs with cooling water intake structures (CWIS) subject to the CWIS requirements.

The conclusions of this review are as follows:

- It is unlikely that any new jackup drilling rigs will enter the GOM fleet by year end 2011.
- Ten newbuild semisubmersible drilling rigs will enter service in the Gulf of Mexico fleet by year-end 2011. Construction of two of these rigs started after July 17, 2006 (Table 1 making them subject to the CWIS regulation.
- Seven newbuild drill ships will enter service in the Gulf of Mexico by year end 2011, Six of the newbuild drill ships were started after July 17, 2006 (Table 1) and are thus subject to CWIS requirements.

# Gulf of Mexico Drilling Rig Fleet

In this report, Rigzone addresses the changes in the number of jackups, drillships and semisubmersible rigs working in the Gulf of Mexico over the previous five years and in the next five years. The Offshore Operators Committee commissioned Rigzone to summarize the information according to data gathered in the company's proprietary RigLogix database, which tracks the offshore rig fleet worldwide.

Rigzone and its predecessor companies have been tracking the offshore drilling rig fleet since 1990, and as such the RigLogix database is one of the most comprehensive and detailed rig databases available anywhere in the world. The system includes detailed specifications for more than 1,200 offshore drilling rigs with additional details on their locations, status, and contracts since 2000. This covers both rigs that are currently in service, as well as those that are being built. This system is used by hundreds of offshore operators, service companies, oilfield equipment manufacturers, insurers, financial analysts and other companies to keep track of offshore drilling activity and to help them plan for changes in the market.

**Newbuild Rigs Entering the US Gulf of Mexico Between 2004 and 2009**
In the last five years, six newbuild jackups entered the GOM within a year of leaving the shipyard. With water depth capacities ranging from 300 to 550 feet, all of these newbuilds were managed by Rowan. While three of the jackups are still located in the US GOM, three have moved on to other areas worldwide.

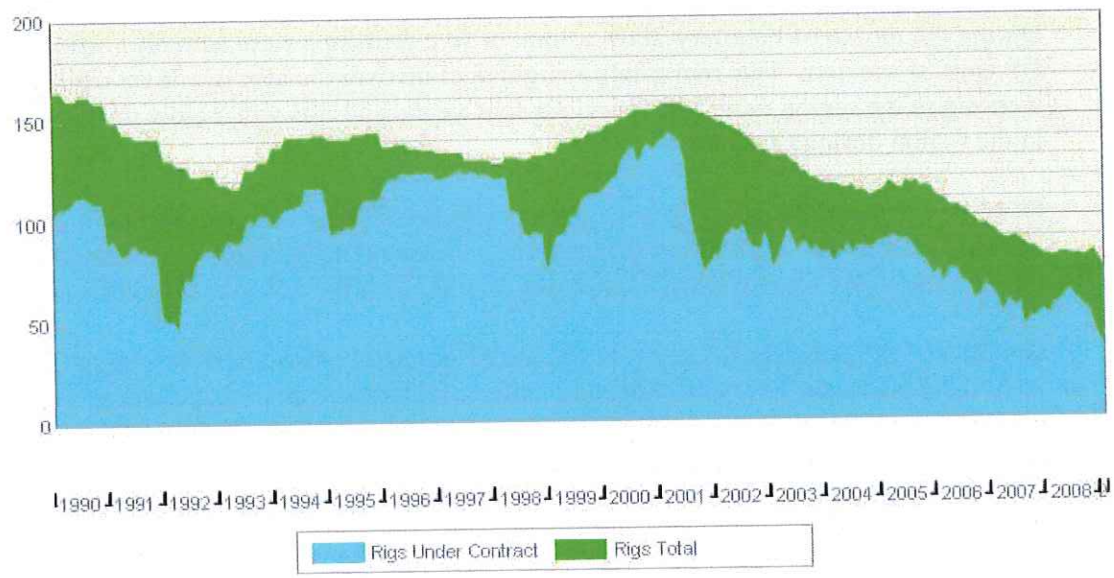
Additionally, three newbuild semisubs entered the US GOM in the last five years, and all of them continue to work in the region. Delivered in early 2005, two of the newbuild semisubs are rated for water depths reaching 7,500 feet deep; while the other semisub was delivered in February 2008 and is rated for 10,000 feet of water.

In the last five years, one newbuild drillship was delivered to the GOM within the first year of leaving the shipyard. Capable of drilling in waters measuring 10,000 feet deep, the Stena DrillMAX was delivered to Repsol for work on Keathley Canyon in January 2008; and the drillship has since moved on to work for Petrobras offshore Brazil.

In all these cases, the existing rigs leaving the US Gulf of Mexico more than offset the newbuilds entering the region. As such, the number of rigs of all three types in the GOM has declined since 2004.

**Future Size of the Jackup Fleet**

Currently the Gulf of Mexico jackup rig fleet is undergoing the largest and most long-lasting contraction that it has experienced at any point since the industry downturn of the mid-1980s. Looking back over the last 18 years, the period from 2001 through 2009 has witnessed a 90 rig reduction in the overall jackup fleet size as the number of rigs in the region has fallen from 164 to 74 rigs at the end of February 2009. The chart below illustrates the contracted and total number of jackup rigs in the US Gulf of Mexico during that time period (see “XOM Jackup Util 1990-2009.xls” for supporting data).




With regard to the reduction in the Gulf of Mexico jackup fleet, the losses that the fleet has experienced over the last eight years are largely the result of stronger demand in other regions of the world coupled with the inherent dangers of operating drilling rigs in the Gulf of Mexico. In particular, Hurricanes Ivan, Katrina, Rita, and Ike combined to destroy a total of 11 jackups while sending many more to the shipyards for extensive repairs. This risk combined with the lucrative long-term contracts to be found in other regions, particularly the Persian Gulf, has driven many rig managers to relocate their jackups to other regions.

Given the unprecedented contraction and historically low utilization rates for jackup rigs in the US Gulf of Mexico, there is very little chance that the jackup rig fleet will expand at any point during the next several years. In fact, by the end of 2009, six more active jackups are expected to leave the US Gulf of Mexico for Mexico, Canada and the Mediterranean. The seven jackups that are under construction at shipyards on the US Gulf Coast are not contracted yet, but are all likely to leave the region when they are completed. If these rigs do not land contracts, then they may stack at ports along the US Gulf Coast.

**Conclusion: Expected Growth in Total Jackup Fleet By Year End 2011: -13 rigs or more**

**Future Size of the Drillship Fleet**
During the month of February 2009, a total of five drillships were actively working in the US Gulf of Mexico. This represents a slight decline over the average of six drillships working in the region during the previous four years, and it is well below the peak of 9 rigs in the region during Q2 2004.

Over the course of the next 2 years, seven newbuild drillships are contracted to enter the US Gulf of Mexico. In addition, Transocean's Deepwater Pathfinder is scheduled to move into the US GOM from West Africa during March 2010 for a 5-year contract with ENI.

One active drillship, Transocean's Discoverer Enterprise, is contracted through the end of 2010 for work in the US Gulf of Mexico, after which time it is likely to leave, although the possibility remains that the rig might have its contract extended. That results in a net increase of seven drillships working in the Gulf of Mexico over the next two years. Please see "XOM Drillship Util 2004-2014.xls" and "Gantt – GOM DS SS – 2009-2014.xls" for details.

**Conclusion: Expected Growth in Total Drillship Fleet By Year End 2011: +7 rigs**

**Future Size of the Semisubmersible Fleet**

During February 2009, a total of 27 semisubmersible rigs were in the waters of the US Gulf of Mexico, of which 24 were under contract for work. This is just below the average of 25 rigs under contract in the region seen over the previous five years, and it is 20% below the peak of 30 semisubs contracted in the GOM which was seen in June 2007.

By mid-2010 a total of nine new deepwater semisubmersible rigs are contracted to move into the Gulf of Mexico. In addition, one further semisub, the ENSCO 8503, is scheduled to arrive in the US GOM during 2011 to make a total of ten newbuild semisubs moving into the region within the next two years.

On the other hand, three semisubs currently in the US GOM are scheduled to leave the region this year. A further five semisubs in the US Gulf of Mexico have contracts ending by April 2010. Of these five rigs with expiring contracts, four belong to Diamond Offshore which has contracted similar rigs to start work in 2009 for OGX offshore Brazil. Therefore, it would not be surprising to see some or all of these rigs move to other regions. A conservative assumption would be that two or three of them will leave the GOM for work elsewhere. However, probably the most likely scenario for these rigs is that most of them will not land new contracts and end up stacking in the Gulf of Mexico waiting for higher levels of rig demand.

As such, the total reduction in the number of semisubs in the Gulf of Mexico would be at least three but likely four or five. Combined with the ten incoming newbuild semisubmersibles, the Gulf of Mexico should see a net increase of six semisubs.
**Conclusion: Expected Growth in Total Semisub Fleet By Year End 2011: +6 rigs**

## Summary of New Drilling Rigs Entering The Gulf of Mexico Fleet by 2011

The cooling water intake structure requirements apply only to facilities for which construction started after July 17, 2006. Table 1 summarizes the contruction start dates and anticipated delivery dates for drilling rigs expected to enter the Gulf of Mexico fleet by year-end 2011.

Table 1. Construction Start and Delivery Dates for Semisubmersible Drilling Rigs and Drillships

| Type of Rig | Started (Mon-YY) | Delivery (Mon-YY) | Rig Owner | Rig |
|---|---|---|---|---|
| Drillship | March-06 | July-09 | Transocean Inc. | Discoverer Clear Leader |
| Drillship | June-06 | July-09 | Transocean Inc. | Discoverer Americas |
| Drillship | September-06 | March-10 | Transocean Inc. | Discoverer Inspiration |
| Drillship | April-07 | April-10 | Pride International | Pride Drillship TBN 1 |
| Drillship | June-07 | January-10 | Frontier Drilling AS | Bully 1 |
| Drillship | July-07 | September-10 | Pride International | Pride Drillship TBN 2 |
| Drillship | December-07 | June-11 | Vantage Energy Services | Titanium Explorer |
| Semisubmersible | January-02 | July-07 | Noble Drilling | Noble Danny Adkins |
| Semisubmersible | January-02 | April-10 | Noble Drilling | Noble Jim Day |
| Semisubmersible | May-05 | April-09 | Maersk Drilling | Maersk Developer |
| Semisubmersible | August-05 | May-09 | Larsen O&G | PetroRig I |
| Semisubmersible | September-05 | April-09 | ENSCO | ENSCO 8500 |
| Semisubmersible | January-06 | September-09 | ENSCO | ENSCO 8501 |
| Semisubmersible | March-06 | June-09 | Transocean Inc. | GSF Development Driller III |
| Semisubmersible | March-06 | March-10 | Saipem | Scarabeo 9 |
| Semisubmersible | September-06 | April-10 | ENSCO | ENSCO 8502 |
| Semisubmersible | June-07 | November-10 | ENSCO | ENSCO 8503 |

## Reference

EPA(2007); "[FRL-8323-5] Notice of Final NPDES General Permit; Final NPDES General Permit for New and Existing Sources and New Dischargers in the Offshore Subcategory of the Oil and Gas Extraction Category for the Western Portion of the Outer Continental Shelf of the Gulf of Mexico (GMG290000) ", 72 Federal Register 109 pp 31565-31578 Accessed at http://epa.gov/region6/water/npdes/genpermt/index.htm#GeneralPermit on 10/29/07

# Appendix D

# Life-History Summary Tables

Table D1. Stage, stage duration, and estimated mortality rates for brown shrimp. See text for additional information.

| Stage | Variable | Case | Value | Comments |
|---|---|---|---|---|
| Eggs | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 1.8971 | Reitsema et al. (1982) reported brown shrimp that averaged 192 mm T.L. released an average of 246,000 viable eggs of which 15% hatched ($S$ = 0.15), $M$ = -ln ($S$) or 1.8971 d$^{-1}$. |
| | | Low | 1.8971 | As above. |
| | | High | 1.8971 | As above. |
| | Stage Duration (Days) | Base | 0.67 | Eggs are demersal and hatch within 24-h after release (Pattillo and Czapla 1997 and references therein). Cook and Lindner (1970) note that in the laboratory the eggs usually hatch within 14 to 18 h. 16 h is the median which is 0.67 d. |
| | | Low | 0.58 | Low end of the 14-18 h hatch time given by Cook and Lindner (1970). |
| | | High | 0.75 | High end of the 14-18 h hatch time given by Cook and Lindner (1970). |
| Larvae | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.1308 | Cook and Murphy (1966) reported that 219 of 1,200 brown shrimp larvae feed on diatoms during early development and brine shrimp at later stages survived to the last mysis stage which occurred 13 days after the start of the experiment. $S$ = 219 ÷ 1,200 = 0.1825; M = -ln (S) = 1.7010. Daily value = 1.7010 ÷ 13 = 0.1308 d$^{-1}$. |
| | | Low | 0.1308 | As above. |
| | | High | 0.1308 | As above. |
| | Stage Duration (Days) | Base | 13.33 | As reported (13 d) by Cook and Murphy (1966) based upon laboratory studies. Added 0.33 to make the egg and larval stages a total of 14 days. |
| | | Low | 10.42 | Lassuy (1983a) and references therein report larvae pass through 5 naupliar, 3 protozoel and 3 mysis stages over a 10 to 25 day period before transforming into postlarvae. Added 0.42 to make egg and larval stages a total of 11 days. |
| | | High | 25.25 | See above. Added 0.25 to make egg and larval stages a total of 26 days. |

Table D1. Continued.

| Stage | Variable | Case | Value | Comments |
|---|---|---|---|---|
| Early Post Larvae | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.0113 | Total stage mortality of 1.7 reported by EPA (2002) based upon Costello and Allen (1970). Total stage duration is estimated at 151 d (below). $M = 1.7 \div 151 = 0.0113$ d$^{-1}$. This stage occurs during fall and winter when temperatures are low and growth is slow but survival is high. Post larvae may spend extensive time burrowed in the sediments. |
| | | Low | 0.0113 | As above. |
| | | High | 0.0113 | As above. |
| | Stage Duration (Days) | Base | 151 | Extended duration of the early postlarvae stage based on Temple and Fischer (1967) and offshore abundance of this stage as reported in the LOOP studies (Sasser and Visser 1999). |
| | | Low | 151 | As above. |
| | | High | 151 | As above. |
| Late Post-Larvae/Early Juvenile | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.0320 | Minello et al. (1989) based upon the average of four cohorts in a Galveston Bay salt marsh. |
| | | Low | 0.0234 | Lowest cohort value observed by Minello et al. (1989). |
| | | High | 0.0554 | Highest cohort value observed by Minello et al. (1989). |
| | Stage Duration (Days) | Base | 61 | Based upon the average of the maximum-minimum size at the end and start of the cohort analysis conducted by Minello et al. (1989) divided by an estimated growth of 1 mm/day. |
| | | Low | 47 | Minimum value derived from the Minello et al. (1989) study. |
| | | High | 72 | Maximum duration derived from the et al. (1989) study. |

Table D1. Continued.

| Stage | Variable | Case | Value | Comments |
|---|---|---|---|---|
| Sub Adult/Adult | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.0092 | Shrimp stock assessment base value (pers. comm., J. Nance, NOAA/NMFS, Galveston Laboratory, TX). |
| | | Low | 0.0067 | Lower end of range in shrimp stock assessment (pers. comm., J. Nance, NOAA/NMFS, Galveston Laboratory, TX). |
| | | High | 0.0117 | Upper end of range in shrimp stock assessment (pers. comm., J. Nance, NOAA/NMFS, Galveston Laboratory, TX). |
| | Stage Duration (Days) | Base | 139 | Balance of year given the above durations of earlier life stages. |
| | | Low | 156 | Balance of year given the above durations of earlier life stages. |
| | | High | 116 | Balance of year given the above durations of earlier life stages. |
| Total Subadult/ Adult Fishing Mortality | | Base | 1.3939 | Ratio of F:M based upon Gazey et al. (1982a, b) = 0.0279 ÷ 0.0256 = 1.09. *M* = daily instantaneous mortality (0.0092) x stage duration (139 days) = 1.2788. F = 1.09 (M) = 1.3939. |
| | | Low | 1.1393 | Ratio of F:M based upon Gazey et al. (1982a, b) = 0.0279 ÷ 0.0256 = 1.09. *M* = daily instantaneous mortality (0.0067) x stage duration (156 days) = 1.0452. F = 1.09 (M) = 1.1393. |
| | | High | 1.4793 | Ratio of F:M based upon Gazey et al. (1982a, b) = 0.0279 ÷ 0.0256 = 1.09. *M* = daily instantaneous mortality (0.0117) x stage duration (116 days) = 1.3572. F = 1.09 (M) = 1.4793. |

Table D2. Stage, stage duration, and estimated mortality rates for white shrimp. See text for additional information.

| Stage | Variable | Case | Value | Comments |
|---|---|---|---|---|
| Eggs | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 1.8971 | As per brown shrimp (Gallaway 2005). (Although spawning occurs in the water column, white shrimp eggs sink to the bottom. Ensuing larval stages are planktonic.) |
| | | Low | 1.8971 | As above. |
| | | High | 1.8971 | As above. |
| | Stage Duration (Days) | Base | 0.46 | Klima et al. (1982) reported that eggs hatch into planktonic nauplii larvae within 10 to 12 hours after fertilization. Mean duration = 0.46 d. |
| | | Low | 0.42 | Low end of the 10-12 h hatch time given by Klima et al. (1982). |
| | | High | 0.50 | High end of the 10-12 h hatch time given by Klima et al. (1982). |
| Larvae | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.1308 | As per brown shrimp (Gallaway 2005). |
| | | Low | 0.1308 | As above. |
| | | High | 0.1308 | As above. |
| | Stage Duration (Days) | Base | 13.33 | As per brown shrimp (Gallaway 2005). |
| | | Low | 10.42 | As per brown shrimp (Gallaway 2005). |
| | | High | 25.25 | As per brown shrimp (Gallaway 2005). |
| Early Post Larvae | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.2429 | Derived by Gallaway (2005). |
| | | Low | 0.2429 | As above. |
| | | High | 0.2429 | As above. |
| | Stage Duration (Days) | Base | 7 | Derived by Gallaway (2005). |
| | | Low | 6 | Derived by Gallaway (2005). |
| | | High | 8 | Derived by Gallaway (2005). |

Table D2. Continued.

| Stage | Variable | Case | Value | Comments |
|---|---|---|---|---|
| Late Post-Larvae/Early Juvenile | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.0320 | As per brown shrimp (Gallaway 2005). |
| | | Low | 0.0234 | As per brown shrimp (Gallaway 2005). |
| | | High | 0.0554 | As per brown shrimp (Gallaway 2005). |
| | Stage Duration (Days) | Base | 61 | As per brown shrimp (Gallaway 2005). |
| | | Low | 47 | As per brown shrimp (Gallaway 2005). |
| | | High | 72 | As per brown shrimp (Gallaway 2005). |
| Sub Adult/Adult | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.0092 | As per brown shrimp (Gallaway 2005). |
| | | Low | 0.0067 | As per brown shrimp (Gallaway 2005). |
| | | High | 0.0117 | As per brown shrimp (Gallaway 2005). |
| | Stage Duration (Days) | Base | 283.7 | Balance of year given the above durations of earlier life stages. |
| | | Low | 301.6 | Balance of year given the above durations of earlier life stages. |
| | | High | 259.8 | Balance of year given the above durations of earlier life stages. |
| Total Subadult/ Adult Fishing Mortality | | Base | 1.5921 | Ratio of F:M based upon Gazey et al. (1982a, b) = 0.0203 ÷ 0.0334 = 0.61. Daily instantaneous mortality (0.0092) x stage duration (283.7 days) = 2.610. F = 0.61 (M) = 1.3939 |
| | | Low | 1.2326 | Ratio of F:M based upon Gazey et al. (1982a, b) = 0.0203 ÷ 0.0334 = 0.61. Daily instantaneous mortality (0.0067) x stage duration (301.6 days) = 2.0207. F = 0.61 (M) = 1.2326 |
| | | High | 1.8542 | Ratio of F:M based upon Gazey et al. (1982a, b) = 0.0203 ÷ 0.0334 = 0.61. Daily instantaneous mortality (0.0117) x stage duration (259.8 days) = 1.0340. F = .61 (M) = 1.8542. |

Table D3. Menhaden life history parameters and the basis for their selection.

| Stage | Variable | Case | Value | Reference & Comments |
|---|---|---|---|---|
| Egg | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 1.044 | EPA (2002) |
| | | Low | 1.044 | EPA (2002) |
| | | High | 6.21 | EPA (2002) |
| | Stage Duration (Days) | Base | 1.75 | e$^2$M (2005) and references therein. Mean of 1.5 d for Gulf menhaden and 2.0 d for yellow menhaden. |
| | | Low | 1.5 | e$^2$M (2005) and references therein. Lower limit of Gulf/yellow menhaden range. |
| | | High | 2.0 | e$^2$M (2005) and references therein. Upper limit of Gulf/yellow menhaden range. |
| Larvae | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.059 | e$^2$M (2005) based on Deegan and Thompson (1987) and Rose (2004; pers. comm.). |
| | | Low | 0.0488 | e$^2$M (2005) based on Deegan and Thompson (1987) and Rose (2004; pers. comm.). |
| | | High | 0.077 | e$^2$M (2005) based on Deegan and Thompson (1987) and Rose (2004; pers. comm.). |
| | Stage Duration (Days) | Base | 65 | e$^2$M (2005) based on Deegan and Thompson (1987) and Rose (2004; pers. comm.). |
| | | Low | 60 | e$^2$M (2005) based on Deegan and Thompson (1987) and Rose (2004; pers. comm.). |
| | | High | 60 | e$^2$M (2005) based on Deegan and Thompson (1987) and Rose (2004; pers. comm.). |
| Juvenile 1 | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.013 | e$^2$M (2005) based on Deegan (1990). |
| | | Low | 0.013 | e$^2$M (2005) based on Deegan (1990). |
| | | High | 0.013 | e$^2$M (2005) based on Deegan (1990). |
| | Stage Duration (Days) | Base | 298.25 | 365 days minus the sum of earlier life-history durations. |
| | | Low | 303.5 | 365 days minus the sum of earlier life-history durations. |
| | | High | 303 | 365 days minus the sum of earlier life-history durations. |

Table D4. Stage, stage duration, and estimated mortality rates for the blue crab. See text for additional information.

| Stage | Variable | Case | Value | Comments |
|---|---|---|---|---|
| Egg | - | - | - | The egg stage is not relevant. Females retain egg masses until they hatch as zoea. |
| Larvae (Zoea-Early Juvenile) | Daily instantaneous mortality ($M$ d$^{-1}$) | Base | 0.3000 | EPA (2002) reported total mortality for these stages combined was 13.8 citing Rose and Cowan (1993). On average these stages occur over a 46-d period. Daily rate = 13.8 ÷ 46 = 0.3000 d$^{-1}$. |
| | | Low | 0.3000 | As above. |
| | | High | 0.3000 | As above. |
| | Stage duration (days) | Base | 46 | Pattillo et al. (1997) reports 31-43 days for development through seven zoeal stages and that 6-12 days were required to develop through the megalopal stage to the first juvenile crab stage. Thus, the total period was from 37-55 days. We used the median 46 days as the base case. |
| | | Low | 37 | Lower limit of Pattillo et al. (1997). |
| | | High | 55 | Upper limit of Pattillo et al. (1997). |
| Juvenile/Adults | Daily instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.0027 | EPA (2002) used an annual rate of M = 1.0 d$^{-1}$which equates to a daily rate of 0.002739. |
| | | Low | 0.0027 | As above. |
| | | High | 0.0027 | AS above. |
| | Stage duration (days) | Base | 319 | Balance of year given the 46-d duration of larval life stages. |
| | | Low | 328 | Balance of year given the 37-d duration of larval life stages. |
| | | High | 310 | Balance of year given the 55-d duration of larval life stages. |

Table D5. Red snapper life history parameters and the basis for their selection. See text for additional information.

| Stage | Variable | Case | Value | Reference & Comments |
|---|---|---|---|---|
| Egg | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.4984 | The value for Atlantic croaker in the Gulf of Mexico from Diamond et al. (1999). |
| | | Low | 0.4984 | The value for Atlantic croaker in the Gulf of Mexico from Diamond et al. (1999). |
| | | High | 0.4984 | The value for Atlantic croaker in the Gulf of Mexico from Diamond et al. (1999). |
| | Stage Duration (Days) | Base | 1 | e$^2$M (2005) and references therein. |
| | | Low | 1 | e$^2$M (2005) and references therein. |
| | | High | 1 | e$^2$M (2005) and references therein. |
| Larvae | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.2413 | Based upon the derivations of Gallaway et al. (2007) with revisions by Gallaway et al. (2009)- see text. Total stage mortality of 6.7564 ÷ 28 days = 0.2413 d$^{-1}$. |
| | | Low | 0.2599 | Total stage mortality of 6.7564 ÷ 26 days (stage duration) = 0.2599 d$^{-1}$. |
| | | High | 0.2252 | Total stage mortality of 6.7564 ÷ 30 days (stage duration) = 0.2252 d$^{-1}$. |
| | Stage Duration (Days) | Base | 28 | Rooker et al. (2004) estimated settlement at 16-19 mm or 27-30 d. Szedlmayer and Conti (1999) suggested metamorphosis occurred at 18 mm or 26 d. The median of 28 d represents the base case. |
| | | Low | 26 | Lower estimate of Rooker et al. (2004) and Szedlmayer and Conti (1999). |
| | | High | 30 | Lower estimate of Rooker et al. (2004) and Szedlmayer and Conti (1999). |
| Juvenile 1 | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.1196 | Based on Gallaway (2005) and Rooker et al. (2004), the estimated $M$ = 0.1196 d$^{-1}$. |
| | | Low | 0.1010 | Lower 95% Confidence Limit of Gallaway (2005). |
| | | High | 0.1382 | Upper 95% Confidence Limit of Gallaway (2005). |
| | Stage Duration (Days) | Base | 38 | Based upon the derivations of Gallaway (2005) - see text. |
| | | Low | 36 | Gallaway (2005). |
| | | High | 40 | Gallaway (2005). |

Table D5. Continued.

| Stage | Variable | Case | Value | Reference & Comments |
|---|---|---|---|---|
| Juvenile 2 | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.0055 | Based upon Gazey et al. (2008) estimate of M = 2.0. Daily instantaneous mortality $M = 2.0 \div 365$ days = 0.0027 d$^{-1}$. |
| | | Low | 0.0055 | As above. |
| | | High | 0.0055 | As above. |
| | Stage Duration (Days) | Base | 117 | Defined as red snapper from 66 days old to the end of the year. The period July-December includes 183 days which minus 66 days results in a stage duration of 117 days. |
| | | Low | 121 | 183 days - 62 days (sum of low case larvae and juvenile 1 stage durations) = 121 days. |
| | | High | 113 | 183 days - 70 days (sum of high case larvae and juvenile 1 stages) = 113 days. |
| Juvenile 3 | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.0032 | Based a annual mortality rate M = 1.2 from Gazey et al. (2008). Dividing 1.2 by 365 days yields $M$ = 0.0032 d$^{-1}$. |
| | | Low | 0.0032 | As above. |
| | | High | 0.0032 | As above. |
| | Stage Duration (Days) | Base | 181 | Remainder of year 1. |
| | | Low | 181 | Remainder of year 1. |
| | | High | 181 | Remainder of year 1. |

Table D6. Yellowfin tuna life history parameters and the basis for their selection. See text for additional information.

| Stage | Variable | Case | Value | Reference & Comments |
|---|---|---|---|---|
| Egg | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 3.54 | Based upon the temperature egg mortality model of Pepin (1991). |
| | | Low | 3.54 | Same as above. |
| | | High | 3.54 | Same as above. |
| | Stage Duration (Days) | Base | 1.34 | Margulies et al. (2007) found that the egg stage duration for yellowfin tuna ranged from 20 to 28 h (0.83-1.17 d) depending upon water temperature (range 24.0-29.5°C). Harada et al. (1980 cited in Pauley and Pullin 1988) reported egg stage durations of 1.34-1.85 depending on temperature (range 18.7-30.1°C). Median value of these values = 1.34. |
| | | Low | 0.83 | Lower limit of studies described above |
| | | High | 1.85 | Upper limit of studies described above |
| Larvae | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.33 | Pooled $M$ of yellowfin larvae collected in the northern GOM (Lang et al. 1994, Grimes and Lang 1992). |
| | | Low | 0.16 | Low end of range reported by Lang et al. (1994). Grimes and Lang (1992) reported a lower $M = 0.27$ d$^{-1}$ |
| | | High | 0.45 | High end of range reported by Lang et al. (1990). Grimes and Lang (1992) reported an upper $M = 0.41$ d$^{-1}$ |
| | Stage Duration (Days) | Base | 16 | Mean of Lang et al. (1990) and Wexler et al. (2007) |
| | | Low | 12 | Low end of range reported by Lang et al. (1994) for yellowfin larvae collected in the northern GOM |
| | | High | 20 | Upper end of age range reported by Wexler et al. (2007) for Pacific yellowfin |

Table D7. Red drum life history parameters and the basis for their selection. See text for additional information.

| Stage | Variable | Case | Value | Reference & Comments |
|---|---|---|---|---|
| Egg | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.4984 | The value for Atlantic croaker in the Gulf of Mexico from Diamond et al. (1999). |
| | | Low | 0.4984 | The value for Atlantic croaker in the Gulf of Mexico from Diamond et al. (1999). |
| | | High | 0.4984 | The value for Atlantic croaker in the Gulf of Mexico from Diamond et al. (1999). |
| | Stage Duration (Days) | Base | 1 | e$^2$M (2005) and references therein. |
| | | Low | 1 | e$^2$M (2005) and references therein. |
| | | High | 1 | e$^2$M (2005) and references therein. |
| Larvae | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.3009 | Comyns (1997) best estimate of larval mortality was 0.33 d$^{-1}$ (SE = 0.04) and covered larvae in the 2.0 to 5.0 mm size range Rooker et al.(1999) estimated juvenile mortality (8 to 20 mm) to be 0.1365 d$^{-1}$. Linear extrapolation between 0.33 d$^{-1}$and 0.1365 d$^{-1}$yields a daily value of 0.23325 d$^{-1}$which was used for larvae between 6 and 8 mm. The composite of the two rates yields a value of 0.3009 d$^{-1}$. |
| | | Low | 0.2225 | Base value minus 95% CI based upon a SE of 0.04 (Comyns 1997). |
| | | High | 0.3793 | Base value plus 95% CI based upon a SE of 0.04 (Comyns 1997). |
| | Stage Duration (Days) | Base | 22 | Rooker et al. (1999) observed peak densities of benthic settlers occurred for individuals 8-9 mm with corresponding ages of 20 to 24 days. For the base case we used the median value of 22 days at settlement to approximate the base-case length of the plankton period. |
| | | Low | 20 | Low end of the range observed by Rooker et al. (1999). |
| | | High | 24 | High end of the range observed by Rooker et al. (1999). |

Table D7. Continued.

| Stage | Variable | Case | Value | Reference & Comments |
|---|---|---|---|---|
| Juvenile 1 | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.1365 | This stage consists of early juveniles of red drum that have settled into benthic habitats at an age of 20-24 d. In Figure 4 of Rooker et al. (1999), settled juvenile 1 drum covers a size range from 8 to 20 mm SL. Observed Z for this size range was 0.134 d$^{-1}$in 1994 and 0.139 d$^{-1}$in 1995 (Rooker et al.1999). We used the mid-point between these two Z values as the base-case estimate. Agreement with e$^2$m (2005). |
| | | Low | 0.134 | Low Z observed by Rooker et al. (1999). Agreement with e$^2$m (2005). |
| | | High | 0.139 | High Z observed by Rooker et al. (1999). Agreement with e$^2$m (2005). |
| | Stage Duration (Days) | Base | 18.5 | This stage consisted of individuals up to 24 mm total length (Rooker et al. 1999). In 1994, 24-mm long fish were 41 days in age whereas in 1995, 24-mm long red drum were about 44 days old. Age at settlement in 1994 was about 21 days indicating a stage duration of 20 days (Rooker et al.1999). In 1995, age at settlement was about 27 days, indicating a stage duration of about 17 days. For the base case we used a stage duration of 18.5 days, the median value. |
| | | Low | 17 | Low duration observed by Rooker et al. (1999). |
| | | High | 20 | High duration observed by Rooker et al. (1999). |

Table D7. Continued.

| Stage | Variable | Case | Value | Reference & Comments |
|---|---|---|---|---|
| Juvenile 2 | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.0094 | Median mortality rates derived from Figure 4 in Scharf (2000) for Galveston and Sabine Lake Estuaries, Dec.-Mar. |
| | | Low | 0.0079 | Galveston Bay mortality rate (Dec.-Mar.) derived from Figure 4 in Scharf (2000). |
| | | High | 0.0108 | Sabine Lake mortality rate (De-Mar.) derived from Figure 4 in Scharf (2000). |
| | Stage Duration (Days) | Base | 168.5 | Based on Scharf (2000) we estimated this stage extends from October-March (180 days). Above we have accounted for 41.5days (from egg to the juvenile 1 stage) which occur in the September/October period. Thus, for the base case, the duration of the juvenile 2 stage is estimated at 168.5 days (180 days-11.5 days in October). |
| | | Low | 172 | In the low case above, egg to the juvenile 1 stage occurs over a total of 38 days (September plus 8 days in October). The stage duration for the low duration estimate is 180 days-8 or 172 days. |
| | | High | 165 | Similarly, the high case described above extends for 45 days. This would allocate 15 days in October; 180-15 yields a stage duration of 165 days. |
| Juvenile 3 | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.0018 | Red drum stock assessment value used for age 0 (Porch 2000). |
| | | Low | 0.0018 | Red drum stock assessment value used for age 0 (Porch 2000). |
| | | High | 0.0018 | Red drum stock assessment value used for age 0 (Porch 2000). |
| | Stage Duration (Days) | Base | 155 | Remainder of year 1. |
| | | Low | 155 | Remainder of year 1. |
| | | High | 155 | Remainder of year 1. |

Table D8. Adult red drum annual mortality rates. Source EPRI (2005).

| Parameter/Age | Stage Mortality |
|---|---|
| M (annual) | |
| Ages 1-5 | 0.23 |
| Ages 6-12 | 0.13 |
| F (annual) | |
| Age 1 | 0.16 |
| Age 2 | 0.49 |
| Age 3 | 0.62 |
| Age 4 | 0.63 |
| Age 5 | 0.39 |
| Age 6+ | 0.39 |

Table D9. Bay anchovy life history parameters and the basis for their selection.

| Stage | Variable | Case | Value | Reference & Comments |
|---|---|---|---|---|
| Egg | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 1.044 | e$^2$M (2005) citing EPRI (2005) and PSEG (1999). |
| | | Low | 0.69 | e$^2$M (2005) citing Houde (1987). |
| | | High | 1.94 | e$^2$M (2005) citing Lowestoft (2000; actual citation is Bunn et al. 2000). |
| | Stage Duration (Days) | Base | 1 | e$^2$M (2005) citing Robinette (1983) and Houde (1987). |
| | | Low | 1 | e$^2$M (2005) citing Robinette (1983) and Houde (1987). |
| | | High | 1 | e$^2$M (2005) citing Robinette (1983) and Houde (1987). |
| Larvae | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.2059 | e$^2$M (2005) citing Houde (1987). |
| | | Low | 0.1804 | e$^2$M (2005) citing Houde (1987). |
| | | High | 0.231 | e$^2$M (2005) citing EPRI (2005) and PSEG (1999). |
| | Stage Duration (Days) | Base | 34 | e$^2$M (2005) citing EPRI (2004) and PSEG (1999). |
| | | Low | 30.63 | e$^2$M (2005) citing EPRI (2005) and PSEG (1999). |
| | | High | 34 | e$^2$M (2005) citing EPRI (2005) and PSEG (1999). |
| Juvenile 1 | Daily Instantaneous Mortality ($M$ d$^{-1}$) | Base | 0.004 | e$^2$M (2005) citing EPRI (2005) and PSEG (1999). |
| | | Low | 0.004 | e$^2$M (2005) citing EPRI (2005) and PSEG (1999). |
| | | High | 0.01 | e$^2$M (2005) citing Houde (1987). |
| | Stage Duration (Days) | Base | 330 | 365 days minus the sum of earlier life-history durations. |
| | | Low | 333.4 | 365 days minus the sum of earlier life-history durations. |
| | | High | 330 | 365 days minus the sum of earlier life-history durations. |

# ADDENDUM

# (REVISED)

## GULF OF MEXICO COOLING WATER INTAKE STRUCTURE: SOURCE WATER BIOLOGICAL BASELINE CHARACTERIZATION STUDY

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## INTRODUCTION

The Offshore Operators Committee's (OOC) Contract 2008-08-01 with LGL Ecological Research Associates, Inc. (LGL) was modified to enable LGL to conduct additional analyses of SEAMAP data as an addendum to the OOC Task 1 Final Project Report "Gulf of Mexico Cooling Water Intake Structure: Source Water Biological Baseline Characterization Study". The objectives of the analyses were to 1) calculate average total density for fish eggs and larvae (all species combined) by a) fishery zone and b) for larvae, total density by month of sampling and zone; and 2) provide species composition and density data for each geographic zone based upon data for all years combined. Background data for these analyses can be found in the referenced final report.

It should be noted that the analyses describing total larvae and egg densities by region and total larval densities by month and region are based on the same sample screening protocols specified in the final report referenced above (samples where both eggs and larvae were analyzed from a sample) whereas all available samples were used to calculate an alternative mean total larvae density estimate by region and to describe the species composition data for each region.

The results of the Source Water Biological Baseline Study were presented to the Environmental Protection Agency on 24 August 2009, and the draft final report was subjected to additional review following this presentation. The major comments included the request that the assessment report describe and evaluate those species most susceptible to impingement and entrainment and provide more information regarding impacts on forage species. The original Addendum provided data listings enabling the requested assessments, however, we have revised the Addendum to specifically address these issues as requested.

## METHODS

A list of the 10 most abundant species was extracted from the overall taxa lists for each of the regions in which new developments are expected (C4, C5, W4, W5). Forage species were identified within these lists. The approach outlined by Gallaway et al. (2007) was used to assess the overall impacts of the new facilities on ecosystem components for which the life-history data were insufficient to support species-specific modeling approaches. In this approach, estimated entrainment losses are compared with the "population" of a larger "reference parcel" or control volume of water. This approach was originally developed to estimate effects of entrainment for proposed Ocean Thermal Energy Conversion projects (e.g., Sinay-Friedman and Reitzel 1980). The control volume consists of one-half the volume of a cylinder of water having a radius equivalent to the distance within approximately 1-day's transport of the intake based upon estimates of median current speed for the region. For the four regions where new development is expected the median current speed for winter and summer are on the order of 0.36 m/s and 0.31 m/s, respectively (Minerals Management Service Gulf of Mexico Region Visual No. 6: Oceanography, Accidents and Vegetation, 1983). The depth of the control volume cylinder was set at 200 m which corresponds to the maximum depth of SEAMAP sampling in deep water in these regions. Most of the new intake structures would also be expected to be located within this depth range or shallower. One-half the Control Volume (C.V.) was calculated in million $m^3$ for each season:

$$C.V. = \frac{\pi r^2 h}{1{,}000{,}000} \times 0.5$$

where r = radius was estimated in m based on median seasonal current speeds, and h (height) was set at 200 m. Based on the median current speed of 0.36 m/s, the cylinder radius r for the winter season was 31,104 m. For the summer season, r was 26,784 m based on the reported median current speed 0.31 m/s.

For assessment purposes, we took the conservative approach of treating the cumulative total intake of all facilities as if it were a single, large facility. In fact, the individual intakes would each be assessed against the control volume and summed. The total daily seawater use in million

$m^3$ was divided by one-half of the control volume of waster passing by the site each day. Assuming a uniform density distribution, the estimated numbers of ichthyoplankton removed on a daily basis would be equivalent to the water-use estimates (i.e., the ichthyoplankton population in the control volume would be estimated by multiplying the volume by the same density estimates used in the entrainment analysis).

## RESULTS

Larval and egg densities by region and month-by-region are shown by Tables 1-3. These estimates are restricted to only those collections where both eggs and larvae were analyzed for a sample. In many samples, egg counts were not made. On a regional basis (Table 1), sample sizes (i.e., tows) ranged from a low of 51 (Region W4) to a high of 778 (Region C5). Both the larvae and egg density data show pronounced decrease with depth in all regions, especially in depth zones 4 and 5 as compared to shallower depths. Most or all new CWIS facilities identified in the final report are projected to occur in depth zones 4 and 5.

Larvae (Table 2) and egg density (Table 3) by month and zone for depth zones where new CWIS development is projected are not only low, as compared to shallower depths, but reflect a much smaller level of monthly variation as compared to that seen for shallower depths. For example, mean larval density in the C1 Region ranged from 0.12 larvae/$m^3$ in February to 23.1 larvae/$m^3$ in July. In contrast, larval density in C5 ranged from 0.13 in March to a high of 0.77 in September. Monthly egg densities in C1 ranged from 1.0 egg/$m^3$ in December to about 20 eggs/$m^3$ in March and August (see Table 3). Egg densities in C5 never reached as high as 1 egg/$m^3$.

Table 4 provides larvae density results based on all samples collected. Sample size by region ranged from 98 (W4) to 1,036 (C5) tows. Larval density patterns were similar to those estimated from the more restricted dataset (compare Table 1 and Table 4). Larval density based on the total samples available show pronounced decreases with depth, especially in depth zones 4 and 5 as compared to shallower depths.

The most abundant taxa in zones where new CWIS development is expected to occur are dominated by forage species (Table 5, complete species composition data are provided in Attachment 1). Region C5 reflected the highest number of total taxa (457) and the top 10 species comprised over 64% of the total density. The number of taxa in each region ranged from a low of 244 (W4) to the high of 457 taxa observed for Region C5. In all cases, the top 10 species comprised over 60% of the total density. Lanternfishes (*Myctophidae*) and bristlemouth (*Gonostomatidae*) typically dominated the forage species represented in the collections.

Lanternfishes are small, deep sea fish that are represented by 246 species in 33 genera and occur in oceans worldwide. They are named after their conspicuous use of bioluminescence. Alexander (1998) suggests that lanternfishes account for as much as 65% of all deep sea fish biomass. Global biomass is estimated to be on the order of 550 to 660 million metric tonnes, several times the entire world's fisheries catch.

Larval myctophids are non-migratory, spending day and night in near surface waters (Ahlstrom 1959). Diel vertical migration is first evident at or shortly after metamorphosis and usually persists throughout the remaining life of the fish (Frost and McCrone 1979). During the day, myctophids stratify in dense aggregations deep in the water column (e.g., $\geq$ 300 m). These aggregations are sufficiently dense to cause deep sound-scattering layers (e.g., Baird et al. 1975, McCartney 1976). At night, they rise to surface water layers presumably to feed on zooplankton. Bristlemouths exhibit similar diel vertical migrations. Although the eggs and larvae occur in surface waters during both day and night, larger specimens are found between 25 to 325 m at night and from 425 to 725 m during the day (Lancraft et al. 1988). In each case, the migratory life stages are larger than the sizes that would be expected to be subject to entrainment and/or impingement.

During winter we estimate that 303,936 million $m^3$ of water would pass our hypothetical facility each day. This hypothetical facility represents the total water use by all the projected new facilities which are estimated to withdraw a total of 1.16969 million $m^3$ of water each day. During winter, the new CWIS facilities would remove 0.00038% of the population passing by the "facility" each day. During summer, the impact would be to remove 0.00052% of the population passing by the facility each day. The projected impacts are small.

## CONCLUSIONS

The ichthyoplankton densities in the geographical regions where new CWIS development is projected are low compared to densities seen in shallower depths. This observation coupled with the projected total water use for all new facilities combined suggest a very small impact overall, especially when compared to the impacts projected for coastal LNG facilities proposed for the Gulf. The combined effects from the seven proposed coastal LNG facilities were all deemed to constitute minor adverse impacts. The level of projected impacts from proposed coastal LNG facilities led us to classify the potential impacts from new CWIS facilities as being "very small".

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Table 1. Larval and Egg Densities by Region.

a) Larval Density

| Regions | Count | Minimum | Maximum | Mean | Sum | Standard Deviation | Variance | Standard Error | CI (95%) |
|---|---|---|---|---|---|---|---|---|---|
| C1 | 352 | 0.00 | 245.88 | 8.78 | 3091.57 | 22.96 | 526.94 | 1.22 | 2.40 |
| C2 | 600 | 0.04 | 83.00 | 4.98 | 2990.72 | 7.26 | 52.69 | 0.30 | 0.58 |
| C3 | 391 | 0.00 | 10.14 | 1.68 | 656.77 | 1.44 | 2.08 | 0.07 | 0.14 |
| C4 | 126 | 0.06 | 4.04 | 0.68 | 85.40 | 0.58 | 0.33 | 0.05 | 0.10 |
| C5 | 778 | 0.00 | 2.45 | 0.42 | 326.91 | 0.28 | 0.08 | 0.01 | 0.02 |
| E1 | 128 | 0.06 | 23.81 | 4.24 | 542.92 | 4.57 | 20.84 | 0.40 | 0.79 |
| E2 | 288 | 0.02 | 31.54 | 3.53 | 1018.02 | 3.87 | 15.01 | 0.23 | 0.45 |
| E3 | 306 | 0.00 | 8.23 | 1.17 | 356.53 | 1.13 | 1.27 | 0.06 | 0.13 |
| E4 | 354 | 0.00 | 2.73 | 0.57 | 201.79 | 0.41 | 0.17 | 0.02 | 0.04 |
| E5 | 352 | 0.00 | 3.50 | 0.39 | 137.36 | 0.29 | 0.09 | 0.02 | 0.03 |
| W1 | 164 | 0.01 | 89.43 | 6.71 | 1100.28 | 11.12 | 123.58 | 0.87 | 1.70 |
| W2 | 413 | 0.00 | 538.00 | 6.58 | 2718.40 | 26.89 | 723.28 | 1.32 | 2.59 |
| W3 | 310 | 0.08 | 19.10 | 2.51 | 777.07 | 2.35 | 5.52 | 0.13 | 0.26 |
| W4 | 51 | 0.11 | 2.36 | 0.52 | 26.37 | 0.40 | 0.16 | 0.06 | 0.11 |
| W5 | 145 | 0.04 | 1.62 | 0.42 | 60.18 | 0.25 | 0.06 | 0.02 | 0.04 |

Table 1. . Continued.

b) Egg Density

| Regions | Count | Minimum | Maximum | Mean | Sum | Standard Deviation | Variance | Standard Error | CI (95%) |
|---|---|---|---|---|---|---|---|---|---|
| C1 | 352 | 0.00 | 168.86 | 10.2516 | 3608.5599 | 22.2440 | 494.7977 | 1.19 | 2.32 |
| C2 | 600 | 0.00 | 207.30 | 4.1685 | 2501.0938 | 10.5791 | 111.9170 | 0.43 | 0.85 |
| C3 | 391 | 0.00 | 5.08 | 0.6336 | 247.7475 | 0.7669 | 0.5881 | 0.04 | 0.08 |
| C4 | 126 | 0.00 | 7.14 | 0.2375 | 29.9310 | 0.7001 | 0.4901 | 0.06 | 0.12 |
| C5 | 778 | 0.00 | 5.10 | 0.0796 | 61.9424 | 0.2150 | 0.0462 | 0.01 | 0.02 |
| E1 | 128 | 0.00 | 74.46 | 4.0953 | 524.1963 | 8.7169 | 75.9840 | 0.77 | 1.51 |
| E2 | 288 | 0.02 | 144.76 | 2.6500 | 763.1989 | 9.1427 | 83.5883 | 0.54 | 1.06 |
| E3 | 306 | 0.00 | 3.64 | 0.3955 | 121.0352 | 0.4033 | 0.1626 | 0.02 | 0.05 |
| E4 | 354 | 0.00 | 13.81 | 0.2274 | 80.5140 | 0.7987 | 0.6379 | 0.04 | 0.08 |
| E5 | 352 | 0.00 | 0.83 | 0.0537 | 18.8961 | 0.0769 | 0.0059 | 0.00 | 0.01 |
| W1 | 164 | 0.00 | 94.82 | 6.1872 | 1014.6964 | 13.7002 | 187.6958 | 1.07 | 2.10 |
| W2 | 413 | 0.00 | 431.00 | 3.5309 | 1458.2520 | 21.5249 | 463.3195 | 1.06 | 2.08 |
| W3 | 310 | 0.02 | 7.35 | 0.4680 | 145.0759 | 0.5992 | 0.3591 | 0.03 | 0.07 |
| W4 | 51 | 0.00 | 0.72 | 0.1157 | 5.8989 | 0.1472 | 0.0217 | 0.02 | 0.04 |
| W5 | 145 | 0.00 | 2.00 | 0.0789 | 11.4406 | 0.1762 | 0.0311 | 0.01 | 0.03 |

Table 2. Larval Density by Region and Month.

| Region | Month | Larval Density (Mean) | Sample Count | STD | SE | CI (95%) |
|---|---|---|---|---|---|---|
| C1 | 2 | 0.12 | 3.00 | 0.16 | 0.09 | 0.18 |
| C1 | 3 | 4.46 | 36.00 | 10.57 | 1.76 | 3.45 |
| C1 | 4 | 1.10 | 3.00 | 1.16 | 0.67 | 1.31 |
| C1 | 5 | 1.45 | 8.00 | 1.29 | 0.46 | 0.89 |
| C1 | 6 | 5.10 | 36.00 | 6.60 | 1.10 | 2.16 |
| C1 | 7 | 23.10 | 71.00 | 40.31 | 4.78 | 9.38 |
| C1 | 8 | 4.59 | 16.00 | 4.67 | 1.17 | 2.29 |
| C1 | 9 | 10.40 | 82.00 | 23.08 | 2.55 | 4.99 |
| C1 | 10 | 3.07 | 26.00 | 3.05 | 0.60 | 1.17 |
| C1 | 11 | 1.19 | 53.00 | 1.25 | 0.17 | 0.34 |
| C1 | 12 | 1.28 | 18.00 | 1.03 | 0.24 | 0.48 |
| C2 | 2 | 0.87 | 5.00 | 0.66 | 0.29 | 0.58 |
| C2 | 3 | 3.53 | 50.00 | 3.55 | 0.50 | 0.99 |
| C2 | 4 | 1.35 | 9.00 | 1.64 | 0.55 | 1.07 |
| C2 | 5 | 5.41 | 2.00 | 6.28 | 4.44 | 8.70 |
| C2 | 6 | 3.40 | 81.00 | 2.47 | 0.27 | 0.54 |
| C2 | 7 | 6.91 | 108.00 | 9.93 | 0.96 | 1.87 |
| C2 | 8 | 3.59 | 28.00 | 3.77 | 0.71 | 1.40 |
| C2 | 9 | 4.94 | 155.00 | 4.71 | 0.38 | 0.74 |
| C2 | 10 | 5.33 | 44.00 | 12.76 | 1.92 | 3.77 |
| C2 | 11 | 5.70 | 108.00 | 8.47 | 0.81 | 1.60 |
| C2 | 12 | 4.88 | 10.00 | 6.20 | 1.96 | 3.85 |
| C3 | 1 | 2.03 | 18.00 | 2.21 | 0.52 | 1.02 |
| C3 | 2 | 1.65 | 7.00 | 0.74 | 0.28 | 0.55 |
| C3 | 3 | 1.77 | 24.00 | 1.74 | 0.36 | 0.70 |
| C3 | 4 | 1.59 | 17.00 | 1.69 | 0.41 | 0.80 |
| C3 | 5 | 1.50 | 84.00 | 0.95 | 0.10 | 0.20 |
| C3 | 6 | 1.24 | 30.00 | 1.35 | 0.25 | 0.48 |
| C3 | 7 | 2.33 | 19.00 | 0.98 | 0.23 | 0.44 |
| C3 | 8 | 1.47 | 19.00 | 1.51 | 0.35 | 0.68 |
| C3 | 9 | 1.70 | 113.00 | 1.42 | 0.13 | 0.26 |
| C3 | 10 | 1.97 | 10.00 | 1.74 | 0.55 | 1.08 |
| C3 | 11 | 1.89 | 46.00 | 1.79 | 0.26 | 0.52 |
| C3 | 12 | 1.01 | 4.00 | 0.72 | 0.36 | 0.71 |
| C4 | 1 | 0.61 | 3.00 | 0.03 | 0.02 | 0.03 |
| C4 | 3 | 0.13 | 1.00 | NA | NA | NA |
| C4 | 4 | 0.50 | 5.00 | 0.26 | 0.12 | 0.23 |
| C4 | 5 | 0.66 | 40.00 | 0.40 | 0.06 | 0.12 |
| C4 | 6 | 0.80 | 11.00 | 0.94 | 0.28 | 0.55 |

Table 2. Continued.

| Region | Month | Larval Density (Mean) | Sample Count | STD | SE | CI (95%) |
|---|---|---|---|---|---|---|
| C4 | 7 | 1.14 | 6.00 | 0.79 | 0.32 | 0.63 |
| C4 | 8 | 0.45 | 17.00 | 0.31 | 0.07 | 0.15 |
| C4 | 9 | 0.92 | 29.00 | 0.74 | 0.14 | 0.27 |
| C4 | 10 | 0.33 | 4.00 | 0.23 | 0.12 | 0.23 |
| C4 | 11 | 0.39 | 8.00 | 0.15 | 0.05 | 0.11 |
| C4 | 12 | 0.18 | 2.00 | 0.02 | 0.01 | 0.03 |
| C5 | 1 | 0.36 | 23.00 | 0.16 | 0.03 | 0.07 |
| C5 | 2 | 0.62 | 9.00 | 0.20 | 0.07 | 0.13 |
| C5 | 3 | 0.13 | 2.00 | 0.09 | 0.06 | 0.12 |
| C5 | 4 | 0.39 | 208.00 | 0.25 | 0.02 | 0.03 |
| C5 | 5 | 0.45 | 441.00 | 0.30 | 0.01 | 0.03 |
| C5 | 6 | 0.37 | 56.00 | 0.28 | 0.04 | 0.07 |
| C5 | 7 | 0.35 | 3.00 | 0.09 | 0.05 | 0.10 |
| C5 | 8 | 0.21 | 13.00 | 0.10 | 0.03 | 0.05 |
| C5 | 9 | 0.77 | 5.00 | 0.40 | 0.18 | 0.35 |
| C5 | 10 | 0.15 | 6.00 | 0.11 | 0.04 | 0.09 |
| C5 | 11 | 0.27 | 1.00 | NA | NA | NA |
| C5 | 12 | 0.31 | 11.00 | 0.16 | 0.05 | 0.09 |
| E1 | 5 | 10.69 | 2.00 | 11.87 | 8.40 | 16.45 |
| E1 | 6 | 0.80 | 2.00 | 0.89 | 0.63 | 1.23 |
| E1 | 7 | 4.61 | 2.00 | 4.33 | 3.06 | 6.00 |
| E1 | 8 | 8.71 | 9.00 | 9.22 | 3.07 | 6.03 |
| E1 | 9 | 3.89 | 92.00 | 3.85 | 0.40 | 0.79 |
| E1 | 10 | 3.54 | 21.00 | 2.70 | 0.59 | 1.15 |
| E2 | 5 | 4.17 | 17.00 | 5.76 | 1.40 | 2.74 |
| E2 | 6 | 1.78 | 13.00 | 1.46 | 0.40 | 0.79 |
| E2 | 7 | 2.17 | 8.00 | 1.76 | 0.62 | 1.22 |
| E2 | 8 | 3.31 | 23.00 | 2.21 | 0.46 | 0.91 |
| E2 | 9 | 3.89 | 158.00 | 4.33 | 0.34 | 0.68 |
| E2 | 10 | 3.14 | 69.00 | 2.93 | 0.35 | 0.69 |
| E3 | 3 | 1.12 | 1.00 | NA | NA | NA |
| E3 | 4 | 0.70 | 25.00 | 0.45 | 0.09 | 0.18 |
| E3 | 5 | 0.94 | 77.00 | 0.92 | 0.10 | 0.20 |
| E3 | 6 | 0.88 | 19.00 | 0.68 | 0.16 | 0.31 |
| E3 | 7 | 0.42 | 7.00 | 0.32 | 0.12 | 0.24 |
| E3 | 8 | 1.18 | 15.00 | 0.98 | 0.25 | 0.50 |
| E3 | 9 | 1.53 | 108.00 | 1.40 | 0.13 | 0.26 |
| E3 | 10 | 1.12 | 53.00 | 1.00 | 0.14 | 0.27 |
| E3 | 12 | 3.76 | 1.00 | NA | NA | NA |

Table 2. Continued.

| Region | Month | Larval Density (Mean) | Sample Count | STD | SE | CI (95%) |
|---|---|---|---|---|---|---|
| E4 | 3 | 0.74 | 6.00 | 0.98 | 0.40 | 0.79 |
| E4 | 4 | 0.70 | 74.00 | 0.47 | 0.05 | 0.11 |
| E4 | 5 | 0.55 | 159.00 | 0.35 | 0.03 | 0.05 |
| E4 | 6 | 0.57 | 30.00 | 0.41 | 0.07 | 0.15 |
| E4 | 7 | 0.34 | 5.00 | 0.18 | 0.08 | 0.16 |
| E4 | 8 | 0.39 | 30.00 | 0.27 | 0.05 | 0.10 |
| E4 | 9 | 0.66 | 28.00 | 0.45 | 0.09 | 0.17 |
| E4 | 10 | 0.40 | 22.00 | 0.30 | 0.06 | 0.12 |
| E5 | 4 | 0.38 | 112.00 | 0.20 | 0.02 | 0.04 |
| E5 | 5 | 0.40 | 207.00 | 0.33 | 0.02 | 0.05 |
| E5 | 6 | 0.41 | 26.00 | 0.30 | 0.06 | 0.11 |
| E5 | 7 | 0.10 | 1.00 | NA | NA | NA |
| E5 | 8 | 0.46 | 2.00 | 0.33 | 0.24 | 0.46 |
| E5 | 10 | 0.60 | 2.00 | 0.40 | 0.28 | 0.55 |
| E5 | 12 | 0.19 | 2.00 | 0.24 | 0.17 | 0.33 |
| W1 | 6 | 5.01 | 20.00 | 5.83 | 1.30 | 2.56 |
| W1 | 7 | 6.82 | 26.00 | 9.04 | 1.77 | 3.48 |
| W1 | 8 | 4.74 | 8.00 | 4.75 | 1.68 | 3.29 |
| W1 | 9 | 9.33 | 72.00 | 14.88 | 1.75 | 3.44 |
| W1 | 10 | 2.67 | 33.00 | 2.86 | 0.50 | 0.98 |
| W1 | 11 | 5.03 | 5.00 | 6.74 | 3.01 | 5.90 |
| W2 | 2 | 3.71 | 1.00 | NA | NA | NA |
| W2 | 4 | 1.66 | 1.00 | NA | NA | NA |
| W2 | 5 | 2.38 | 13.00 | 2.18 | 0.60 | 1.18 |
| W2 | 6 | 4.73 | 81.00 | 3.79 | 0.42 | 0.83 |
| W2 | 7 | 4.76 | 58.00 | 8.37 | 1.10 | 2.15 |
| W2 | 8 | 27.40 | 26.00 | 104.31 | 20.46 | 40.10 |
| W2 | 9 | 6.65 | 128.00 | 6.60 | 0.58 | 1.14 |
| W2 | 10 | 4.35 | 96.00 | 5.32 | 0.54 | 1.06 |
| W2 | 11 | 4.62 | 9.00 | 2.42 | 0.81 | 1.58 |
| W3 | 1 | 1.13 | 10.00 | 0.28 | 0.09 | 0.17 |
| W3 | 2 | 1.04 | 4.00 | 0.38 | 0.19 | 0.37 |
| W3 | 4 | 1.20 | 6.00 | 0.84 | 0.34 | 0.67 |
| W3 | 5 | 2.01 | 35.00 | 1.74 | 0.29 | 0.58 |
| W3 | 6 | 2.62 | 40.00 | 1.97 | 0.31 | 0.61 |
| W3 | 7 | 2.65 | 36.00 | 2.87 | 0.48 | 0.94 |
| W3 | 8 | 2.72 | 17.00 | 2.11 | 0.51 | 1.00 |
| W3 | 9 | 2.82 | 104.00 | 2.36 | 0.23 | 0.45 |
| W3 | 10 | 2.57 | 55.00 | 2.87 | 0.39 | 0.76 |

Table 2. Continued.

| Region | Month | Larval Density (Mean) | Sample Count | STD | SE | CI (95%) |
|---|---|---|---|---|---|---|
| W3 | 11 | 0.99 | 3.00 | 0.67 | 0.39 | 0.76 |
| W4 | 1 | 0.51 | 3.00 | 0.19 | 0.11 | 0.21 |
| W4 | 2 | 0.83 | 2.00 | 0.33 | 0.24 | 0.46 |
| W4 | 4 | 0.37 | 2.00 | 0.36 | 0.25 | 0.50 |
| W4 | 5 | 0.51 | 17.00 | 0.37 | 0.09 | 0.18 |
| W4 | 6 | 0.69 | 2.00 | 0.39 | 0.27 | 0.53 |
| W4 | 7 | 0.27 | 12.00 | 0.16 | 0.05 | 0.09 |
| W4 | 8 | 0.23 | 2.00 | 0.05 | 0.03 | 0.07 |
| W4 | 9 | 0.79 | 11.00 | 0.56 | 0.17 | 0.33 |
| W5 | 1 | 0.29 | 17.00 | 0.12 | 0.03 | 0.06 |
| W5 | 2 | 0.43 | 5.00 | 0.14 | 0.06 | 0.12 |
| W5 | 4 | 0.31 | 27.00 | 0.24 | 0.05 | 0.09 |
| W5 | 5 | 0.47 | 87.00 | 0.26 | 0.03 | 0.05 |
| W5 | 6 | 0.52 | 3.00 | 0.23 | 0.13 | 0.26 |
| W5 | 7 | 0.18 | 2.00 | 0.05 | 0.04 | 0.07 |
| W5 | 8 | 0.54 | 2.00 | 0.23 | 0.16 | 0.32 |
| W5 | 9 | 0.30 | 2.00 | 0.02 | 0.02 | 0.03 |

Table 3. Egg Density by Region and Month.

| Region | Month | Egg Density (Mean) | Sample Count | STD | SE | CI (95%) |
|---|---|---|---|---|---|---|
| C1 | 2 | 1.89 | 3 | 2.54 | 1.47 | 2.87 |
| C1 | 3 | 20.65 | 36 | 30.76 | 5.13 | 10.05 |
| C1 | 4 | 10.83 | 3 | 5.28 | 3.05 | 5.98 |
| C1 | 5 | 1.88 | 8 | 2.97 | 1.05 | 2.06 |
| C1 | 6 | 16.17 | 36 | 32.36 | 5.39 | 10.57 |
| C1 | 7 | 13.87 | 71 | 18.51 | 2.20 | 4.31 |
| C1 | 8 | 20.99 | 16 | 43.23 | 10.81 | 21.18 |
| C1 | 9 | 7.56 | 82 | 17.73 | 1.96 | 3.84 |
| C1 | 10 | 3.33 | 26 | 7.10 | 1.39 | 2.73 |
| C1 | 11 | 3.49 | 53 | 14.20 | 1.95 | 3.82 |
| C1 | 12 | 1.00 | 18 | 2.04 | 0.48 | 0.94 |
| C2 | 2 | 17.43 | 5 | 21.30 | 9.53 | 18.67 |
| C2 | 3 | 9.91 | 50 | 29.23 | 4.13 | 8.10 |
| C2 | 4 | 5.42 | 9 | 6.19 | 2.06 | 4.04 |
| C2 | 5 | 19.92 | 2 | 25.18 | 17.81 | 34.90 |
| C2 | 6 | 3.48 | 81 | 3.59 | 0.40 | 0.78 |
| C2 | 7 | 5.58 | 108 | 8.87 | 0.85 | 1.67 |
| C2 | 8 | 3.79 | 28 | 4.00 | 0.76 | 1.48 |
| C2 | 9 | 2.89 | 155 | 5.67 | 0.46 | 0.89 |
| C2 | 10 | 2.22 | 44 | 5.08 | 0.77 | 1.50 |
| C2 | 11 | 1.93 | 108 | 2.45 | 0.24 | 0.46 |
| C2 | 12 | 8.54 | 10 | 12.34 | 3.90 | 7.65 |
| C3 | 1 | 0.81 | 18 | 0.64 | 0.15 | 0.30 |
| C3 | 2 | 0.78 | 7 | 0.71 | 0.27 | 0.52 |
| C3 | 3 | 1.24 | 24 | 1.48 | 0.30 | 0.59 |
| C3 | 4 | 0.56 | 17 | 0.30 | 0.07 | 0.14 |
| C3 | 5 | 0.63 | 84 | 0.53 | 0.06 | 0.11 |
| C3 | 6 | 0.62 | 30 | 0.75 | 0.14 | 0.27 |
| C3 | 7 | 0.90 | 19 | 1.15 | 0.26 | 0.52 |
| C3 | 8 | 0.76 | 19 | 0.71 | 0.16 | 0.32 |
| C3 | 9 | 0.47 | 113 | 0.57 | 0.05 | 0.10 |
| C3 | 10 | 0.77 | 10 | 1.47 | 0.47 | 0.91 |
| C3 | 11 | 0.51 | 46 | 0.74 | 0.11 | 0.21 |
| C3 | 12 | 0.25 | 4 | 0.20 | 0.10 | 0.20 |
| C4 | 1 | 0.12 | 3 | 0.13 | 0.08 | 0.15 |
| C4 | 3 | 0.31 | 1 | NA | NA | NA |
| C4 | 4 | 0.19 | 5 | 0.18 | 0.08 | 0.16 |
| C4 | 5 | 0.19 | 40 | 0.41 | 0.06 | 0.13 |
| C4 | 6 | 0.41 | 11 | 0.68 | 0.20 | 0.40 |

Table 3. Continued.

| Region | Month | Egg Density (Mean) | Sample Count | STD | SE | CI (95%) |
|---|---|---|---|---|---|---|
| C4 | 7 | 0.26 | 6 | 0.18 | 0.07 | 0.15 |
| C4 | 8 | 0.18 | 17 | 0.20 | 0.05 | 0.10 |
| C4 | 9 | 0.36 | 29 | 1.31 | 0.24 | 0.48 |
| C4 | 10 | 0.08 | 4 | 0.07 | 0.04 | 0.07 |
| C4 | 11 | 0.06 | 8 | 0.11 | 0.04 | 0.08 |
| C4 | 12 | 0.22 | 2 | 0.16 | 0.11 | 0.22 |
| C5 | 1 | 0.07 | 23 | 0.15 | 0.03 | 0.06 |
| C5 | 2 | 0.61 | 9 | 1.68 | 0.56 | 1.10 |
| C5 | 3 | 0.21 | 2 | 0.01 | 0.01 | 0.02 |
| C5 | 4 | 0.07 | 208 | 0.10 | 0.01 | 0.01 |
| C5 | 5 | 0.07 | 441 | 0.08 | 0.00 | 0.01 |
| C5 | 6 | 0.06 | 56 | 0.05 | 0.01 | 0.01 |
| C5 | 7 | 0.07 | 3 | 0.03 | 0.02 | 0.04 |
| C5 | 8 | 0.32 | 13 | 0.55 | 0.15 | 0.30 |
| C5 | 9 | 0.04 | 5 | 0.03 | 0.01 | 0.02 |
| C5 | 10 | 0.03 | 6 | 0.02 | 0.01 | 0.02 |
| C5 | 11 | 0.01 | 1 | NA | NA | NA |
| C5 | 12 | 0.10 | 11 | 0.24 | 0.07 | 0.14 |
| E1 | 5 | 11.57 | 2 | 12.73 | 9.00 | 17.65 |
| E1 | 6 | 12.74 | 2 | 13.33 | 9.42 | 18.47 |
| E1 | 7 | 37.73 | 2 | 51.95 | 36.73 | 71.99 |
| E1 | 8 | 8.51 | 9 | 8.60 | 2.87 | 5.62 |
| E1 | 9 | 3.26 | 92 | 5.79 | 0.60 | 1.18 |
| E1 | 10 | 1.14 | 21 | 1.03 | 0.23 | 0.44 |
| E2 | 5 | 4.30 | 17 | 6.09 | 1.48 | 2.89 |
| E2 | 6 | 1.90 | 13 | 2.06 | 0.57 | 1.12 |
| E2 | 7 | 1.87 | 8 | 1.71 | 0.61 | 1.19 |
| E2 | 8 | 4.01 | 23 | 7.00 | 1.46 | 2.86 |
| E2 | 9 | 3.06 | 158 | 11.81 | 0.94 | 1.84 |
| E2 | 10 | 1.09 | 69 | 0.86 | 0.10 | 0.20 |
| E3 | 3 | 1.23 | 1 | NA | NA | NA |
| E3 | 4 | 0.64 | 25 | 0.75 | 0.15 | 0.30 |
| E3 | 5 | 0.40 | 77 | 0.33 | 0.04 | 0.07 |
| E3 | 6 | 0.37 | 19 | 0.21 | 0.05 | 0.09 |
| E3 | 7 | 0.39 | 7 | 0.24 | 0.09 | 0.18 |
| E3 | 8 | 0.61 | 15 | 0.53 | 0.14 | 0.27 |
| E3 | 9 | 0.35 | 108 | 0.37 | 0.04 | 0.07 |
| E3 | 10 | 0.30 | 53 | 0.29 | 0.04 | 0.08 |
| E3 | 12 | 0.18 | 1 | NA | NA | NA |

Table 3. Continued.

| Region | Month | Egg Density (Mean) | Sample Count | STD | SE | CI (95%) |
|---|---|---|---|---|---|---|
| E4 | 3 | 0.30 | 6 | 0.35 | 0.14 | 0.28 |
| E4 | 4 | 0.18 | 74 | 0.32 | 0.04 | 0.07 |
| E4 | 5 | 0.29 | 159 | 1.15 | 0.09 | 0.18 |
| E4 | 6 | 0.20 | 30 | 0.30 | 0.06 | 0.11 |
| E4 | 7 | 0.07 | 5 | 0.06 | 0.03 | 0.05 |
| E4 | 8 | 0.13 | 30 | 0.21 | 0.04 | 0.07 |
| E4 | 9 | 0.23 | 28 | 0.35 | 0.07 | 0.13 |
| E4 | 10 | 0.12 | 22 | 0.18 | 0.04 | 0.08 |
| E5 | 4 | 0.05 | 112 | 0.06 | 0.01 | 0.01 |
| E5 | 5 | 0.06 | 207 | 0.09 | 0.01 | 0.01 |
| E5 | 6 | 0.06 | 26 | 0.05 | 0.01 | 0.02 |
| E5 | 7 | 0.13 | 1 | NA | NA | NA |
| E5 | 8 | 0.02 | 2 | 0.00 | 0.00 | 0.00 |
| E5 | 10 | 0.02 | 2 | 0.02 | 0.01 | 0.03 |
| E5 | 12 | 0.02 | 2 | 0.03 | 0.02 | 0.04 |
| W1 | 6 | 6.84 | 20 | 6.34 | 1.42 | 2.78 |
| W1 | 7 | 11.03 | 26 | 20.49 | 4.02 | 7.88 |
| W1 | 8 | 12.62 | 8 | 28.93 | 10.23 | 20.05 |
| W1 | 9 | 6.20 | 72 | 12.65 | 1.49 | 2.92 |
| W1 | 10 | 0.80 | 33 | 1.17 | 0.20 | 0.40 |
| W1 | 11 | 3.39 | 5 | 5.67 | 2.54 | 4.97 |
| W2 | 2 | 0.60 | 1 | NA | NA | NA |
| W2 | 4 | 0.61 | 1 | NA | NA | NA |
| W2 | 5 | 2.51 | 13 | 0.90 | 0.25 | 0.49 |
| W2 | 6 | 3.36 | 81 | 2.44 | 0.27 | 0.53 |
| W2 | 7 | 3.28 | 58 | 5.92 | 0.78 | 1.52 |
| W2 | 8 | 21.79 | 26 | 84.32 | 16.54 | 32.41 |
| W2 | 9 | 2.28 | 128 | 2.51 | 0.22 | 0.44 |
| W2 | 10 | 0.98 | 96 | 1.72 | 0.18 | 0.34 |
| W2 | 11 | 1.11 | 9 | 0.75 | 0.25 | 0.49 |
| W3 | 1 | 0.22 | 10 | 0.11 | 0.04 | 0.07 |
| W3 | 2 | 0.32 | 4 | 0.17 | 0.09 | 0.17 |
| W3 | 4 | 0.53 | 6 | 0.38 | 0.16 | 0.31 |
| W3 | 5 | 0.66 | 35 | 0.54 | 0.09 | 0.18 |
| W3 | 6 | 0.68 | 40 | 0.72 | 0.11 | 0.22 |
| W3 | 7 | 0.63 | 36 | 1.19 | 0.20 | 0.39 |
| W3 | 8 | 0.54 | 17 | 0.44 | 0.11 | 0.21 |
| W3 | 9 | 0.44 | 104 | 0.40 | 0.04 | 0.08 |
| W3 | 10 | 0.20 | 55 | 0.17 | 0.02 | 0.05 |

Table 3. Continued.

| Region | Month | Egg Density (Mean) | Sample Count | STD | SE | CI (95%) |
|---|---|---|---|---|---|---|
| W3 | 11 | 0.11 | 3 | 0.07 | 0.04 | 0.08 |
| W4 | 1 | 0.04 | 3 | 0.04 | 0.02 | 0.04 |
| W4 | 2 | 0.06 | 2 | 0.04 | 0.03 | 0.05 |
| W4 | 4 | 0.07 | 2 | 0.02 | 0.01 | 0.03 |
| W4 | 5 | 0.12 | 17 | 0.17 | 0.04 | 0.08 |
| W4 | 6 | 0.10 | 2 | 0.11 | 0.08 | 0.15 |
| W4 | 7 | 0.17 | 12 | 0.18 | 0.05 | 0.10 |
| W4 | 8 | 0.02 | 2 | 0.02 | 0.02 | 0.03 |
| W4 | 9 | 0.12 | 11 | 0.13 | 0.04 | 0.08 |
| W5 | 1 | 0.03 | 17 | 0.02 | 0.01 | 0.01 |
| W5 | 2 | 0.02 | 5 | 0.01 | 0.00 | 0.01 |
| W5 | 4 | 0.08 | 27 | 0.06 | 0.01 | 0.02 |
| W5 | 5 | 0.08 | 87 | 0.21 | 0.02 | 0.04 |
| W5 | 6 | 0.20 | 3 | 0.22 | 0.13 | 0.25 |
| W5 | 7 | 0.38 | 2 | 0.21 | 0.15 | 0.29 |
| W5 | 8 | 0.01 | 2 | 0.00 | 0.00 | 0.00 |
| W5 | 9 | 0.09 | 2 | 0.05 | 0.04 | 0.07 |

Table 4. Mean larval density by region based on all samples.

| Region | Sum Of Densities | No of Trawls | Average Density |
|---|---|---|---|
| C1 | 5466.25 | 1029 | 5.31219 |
| C2 | 4730.58 | 1167 | 4.05362 |
| C3 | 861.80 | 577 | 1.49359 |
| C4 | 120.56 | 193 | 0.62468 |
| C5 | 384.15 | 1036 | 0.37081 |
| E1 | 1275.07 | 229 | 5.56798 |
| E2 | 1829.43 | 471 | 3.88415 |
| E3 | 494.00 | 434 | 1.13825 |
| E4 | 248.65 | 475 | 0.52348 |
| E5 | 151.52 | 419 | 0.36163 |
| W1 | 1614.33 | 253 | 6.38074 |
| W2 | 3470.34 | 596 | 5.82272 |
| W3 | 1064.04 | 430 | 2.47450 |
| W4 | 48.63 | 98 | 0.49618 |
| W5 | 91.07 | 220 | 0.41394 |

Table 5. Most abundant species in zones where new development is expected to occur.

| Region | Taxa | Common Name | Density (No.m$^3$) | Cumulative Percent of Total Catch | Ecosystem Designation |
|---|---|---|---|---|---|
| **C4** | Engraulidae | Anchovies | 0.06012 | 9.6 | Forage |
| 321 Total Taxa | Myctophidae | Lanternfishes | 0.05834 | 19.0 | Forage |
| | *Bregmaceros* spp. | Codlets | 0.04864 | 26.8 | Forage |
| | *Diaphus* spp. | Lanternfishes | 0.04681 | 34.2 | Forage |
| | *Gonostomatidae* | Bristlemouths | 0.04501 | 41.4 | Forage |
| | Gobiidae | Gobies | 0.03966 | 47.8 | |
| | Unidentified Fish | | 0.03274 | 53.0 | |
| | Synodontidae | Lizardfishes | 0.01990 | 56.2 | Forage |
| | *Hygophum* spp. | Lanternfishes | 0.01511 | 58.6 | Forage |
| | *Maurolicus muelleri* | Mueller's bristlemouth | 0.01506 | 61.1 | Forage |
| | **Total Mean Density All taxa** | | **0.62468** | | |

| Region | Taxa | Common Name | Density (No.m$^3$) | Cumulative Percent of Total Catch | Ecosystem Designation |
|---|---|---|---|---|---|
| **C5** | Myctophidae | Lanternfishes | 0.05194 | 14.0 | Forage |
| 457 Total Taxa | *Diaphus* spp. | Lanternfishes | 0.04056 | 24.9 | Forage |
| | *Gonostomatidae* | Bristlemouths | 0.02592 | 31.9 | Forage |
| | *Hygophum* spp. | Lanternfishes | 0.02566 | 38.9 | Forage |
| | Unidentified Fish | | 0.02382 | 45.3 | |
| | *Cyclothone* spp. | Bristlemouths | 0.01906 | 50.4 | Forage |
| | *Myctophum* spp. | Lanternfishes | 0.01606 | 54.8 | Forage |
| | *Bregmaceros* spp. | Codlets | 0.01248 | 58.1 | Forage |
| | *Benthosema* spp. | Lanternfishes | 0.01189 | 61.3 | Forage |
| | *Notolychnus valdiviae* | Lanternfish | 0.00778 | 63.4 | Forage |
| | **Total Density All taxa** | | **0.37075** | | |

| Region | Taxa | Common Name | Density (No.m$^3$) | Cumulative Percent of Total Catch | Ecosystem Designation |
|---|---|---|---|---|---|
| **W4** | Myctophidae | Lanternfishes | 0.07271 | 14.7 | Forage |
| 244 Total Taxa | *Bregmaceros* spp. | Codlets | 0.04734 | 24.2 | Forage |
| | Gobiidae | Gobies | 0.03816 | 31.9 | |
| | *Diaphus* spp. | Lanternfishes | 0.03441 | 38.8 | Forage |
| | *Hygophum* spp. | Lanternfishes | 0.02711 | 44.3 | Forage |
| | *Gonostomatidae* | Bristlemouths | 0.02587 | 49.5 | Forage |
| | Unidentified Fish | | 0.01951 | 53.4 | |
| | *Cyclothone* spp. | Bristlemouths | 0.01935 | 57.3 | Forage |
| | Engraulidae | Anchovies | 0.01616 | 60.6 | Forage |
| | Scombridae | Mackerels | 0.01013 | 62.6 | |
| | **Total Density All taxa** | | **0.49618** | | |

Table 5. Continued.

| Region | Taxa | Common Name | Density (No.m$^{3}$) | Cumulative Percent of Total Catch | Ecosystem Designation |
|---|---|---|---|---|---|
| **W5**<br>284 Total Taxa | Myctophidae | Lanternfishes | 0.05889 | 14.2 | Forage |
| | *Gonostomatidae* | Bristlemouths | 0.03183 | 21.9 | Forage |
| | *Bregmaceros* spp. | Codlets | 0.02976 | 29.1 | Forage |
| | *Cyclothone* spp. | Bristlemouths | 0.02631 | 35.5 | Forage |
| | *Diaphus* spp. | Lanternfishes | 0.02392 | 41.2 | Forage |
| | Unidentified Fish | | 0.02049 | 46.2 | |
| | Gobiidae | Gobies | 0.01978 | 51.0 | |
| | *Hygophum* spp. | Lanternfishes | 0.01523 | 54.6 | Forage |
| | *Benthosema* spp. | Lanternfishes | 0.01279 | 57.7 | Forage |
| | *Notolychnus valdiviae* | Lanternfish | 0.01124 | 60.5 | Forage |
| | **Total Density All taxa** | | **0.41393** | | |